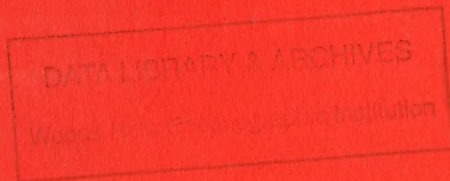


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U.S. Army Coastal Engineering Research Center

DYNAMIC PROPERTIES OF IMMERSED SAND AT VIRGINIA BEACH, VIRGINIA



TECHNICAL MEMORANDUM NO. 9

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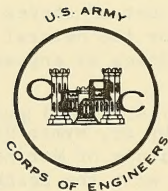
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DYNAMIC PROPERTIES OF IMMERSED SAND AT VIRGINIA BEACH, VIRGINIA

by
W. Harrison
and
R. Morales Alamo



TECHNICAL MEMORANDUM NO. 9
December 1964

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FOREWORD

Information is scanty relative to mean settling velocities of sand samples from natural beaches. Nevertheless, for many studies it is desirable to obtain measurements of the mean still-water settling velocities of natural aggregates of sand-sized material because the settling velocity of an individual particle in quiescent water is the most fundamental hydraulic characteristic that can be measured. This study was designed to measure and record the systematic variations in mean settling velocity of a large number of sand samples taken simultaneously along three transects across a natural beach and in the area around the mouth of an inlet associated with the beach.

Results of the measurements of mean settling velocities presented in this technical memorandum are for quiescent water of the temperature encountered during sampling and the derived dynamic properties of mean Reynolds number and mean drag coefficient are also for an infinite column of quiescent sea water at the natural temperature. The various dynamic properties are tabulated and a set of curves is presented so that the mean settling velocities observed for the natural water temperature (6.9°) can be converted to settling velocities at any water temperature between 0° and 36° C.

This report was prepared by Dr. Wyman Harrison, Associate Marine Scientist of the Virginia Institute of Marine Science, in pursuance of Contract DA-49-055-CIVENG-63-6 with the Beach Erosion Board, and in collaboration with Mr. Reinaldo Morales-Alamo, a graduate student at the Institute.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945, as supplemented by Public Law 172, 88th Congress, approved November 7, 1963.

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LIST OF NOTATIONS

- a - Long axis of a particle or boundary reference - axis distance.
- A - Cross-sectional area of an immersed body
- b - Intermediate axis of a particle
- c - Short axis of a particle
- C - A numerical resistance coefficient
- C_D - Drag coefficient of a particle (for an infinite, quiescent fluid)
- C_{Dn} - Drag coefficient corresponding to a given R_n value.
- d_n - Nominal diameter of a particle (the diameter of a sphere having the same volume as the particle).
- D - Diameter of an immersed particle
- D_e - Diameter of a sand grain as determined from "equilibrium" criterion
- F - Force resisting motion of an immersed body
- F_B - Buoyancy force
- F_g - Gravitational force
- F_r - Fluid resistance force
- G - Gravitational constant
- h - Water depth
- H_o - Wave height in deep water
- k - Wave number
- k_e - Effective hydraulic roughness length
- L_o - Wave length in deep water
- M_v - Mean settling velocity of sand sample (as measured in settling tube).
- M_z - Mean size (in nominal diameter) of a sand sample.
- P - Probability level indicated by a statistical test or percentile of output curve from sand analyzer.
- r - Radius of spherical particle
- R_e - Reynolds number

- R_n - Reynolds number for mean nominal sphere
- S - Slope of energy gradient
- S_o - Sorting coefficient of sand sample
- t_d - Depth of flow
- V - Particle velocity
- V_e - Mean backwash edge velocity
- V_n - Settling velocity of nominal sphere
- V_p - Terminal settling velocity in quiescent fluid
- w - Terminal fall velocity of particle. (Equivalent to V_p)
- α - Beach slope
- μ - Dynamic viscosity
- ν - Kinematic viscosity
- ρ_f - Fluid density
- ρ_s - Particle (solid) density
- Ω - Geometric expression of shape

DYNAMIC PROPERTIES OF IMMERSED SAND
AT VIRGINIA BEACH, VIRGINIA

by

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ABSTRACT

On March 25, 1963, 219 sand samples were taken from the shoaling-wave, breaking-wave, swash-backwash, and foreshore zones of the beach. The following kinds of measurements were used to describe the properties of the samples: mean settling velocity in nature (as determined with a Woods Hole Rapid Sand Analyzer and a special set of curves for settling velocity as a function of temperature), mean Reynolds number (in nature), and mean drag coefficient (for an infinite fluid under natural conditions). Corey's (1949) shape factor and the Dynamic Shape Factor of Briggs, et al. (1962) were calculated and compared; the Corey shape factor was used in calculating mean settling velocity. Also presented are data for mean and median grain size (in nominal diameter) and sorting for each sample. For the natural sea-water conditions ($T = 6.9^{\circ}\text{C}$, $S = 26.7$ o/oo), average Reynolds numbers for the various zones were 4.8 (shoaling-wave), 8.1 (breaking-wave), 6.2 (swash-backwash) and 12.0 (swash-berm).

The important effect of kinematic viscosity on the dynamic properties of the particles and on beach slopes in the shoaling wave zone is considered. Observed trends of mean size and sorting throughout the dynamic zones are compared with those predicted by Miller and Zeigler's (1958) model and the comparison is found to be rather poor.

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INTRODUCTION

Fundamental to an understanding of the interaction of a particular beach with the forces exerted upon it by the impinging water body is an assessment of the dynamic behavior of the particles that comprise the beach, under the expectable wave and current forces. To this end it is necessary, first of all, to undertake the description of the dynamic and associated properties of the existing spectrum of sand-sized particles. The method of description chosen here for samples of sand from Virginia Beach (Figure 1) is based upon the measured dynamic property of settling velocity. Mean settling velocities of sand samples are determined from fall-tube settling velocity curves by statistical methods. From a given mean settling velocity the derived dynamic properties of mean Reynolds number, mean drag coefficient, and mean dynamic shape factor are determined for a sample. Mean grain size, in terms of nominal diameter, and sorting are also determined.

REVIEW OF PREVIOUS WORK

The significance of the settling velocity of sediment particles in the study of their dynamic properties has been stressed by many investigators. Brown (1950) states that many of the hydraulic properties that control the entrainment, transportation, and deposition of mineral particles apparently also control the dynamics of the mineral particles falling through the fluid. Briggs, et al. (1962), consider that settling velocity is perhaps the most fundamental of these hydraulic properties. The U. S. Inter-Agency Committee on Water Resources (1958) considers that the settling velocity of the individual particle in quiescent water is the most fundamental hydraulic characteristic which can be measured; that the physical properties of the particles greatly affect their settling velocity but are not in themselves adequate measures of their behavior in motion in a fluid; and that studies of transport of sediments in water bodies require a knowledge of the dynamic properties of the particles.

The settling velocity of a particle through a fluid medium is essentially determined by the force that resists motion of an immersed body. Newton (1687) considered this resisting force (F) to depend upon the cross sectional area of the body (A), the mass density of the particle (ρ_s), and the square of the velocity (V).

$$F = (C) A \rho_s \frac{V^2}{2} \quad (1)$$

The term C is a numerical resistance coefficient which Newton believed to vary only with the shape of the body and its orientation with respect to the direction of motion. Rouse (1937) considers Newton's equation dimensionally correct but states that the resistance coefficient depends not only

upon shape and orientation but varies considerably with the viscous characteristics of the motion.

Reynolds (1883) showed that the influence of viscosity depends upon the dynamic viscosity of the fluid (μ), the fluid density (ρ_f), the size of the body (D), and the mean velocity of the relative motion (V). Reynolds combined these parameters as a dimensionless ratio called the Reynolds number (R_e):

$$R_e = \frac{VD\rho_f}{\mu} = \frac{VD}{\nu} \quad (2)$$

where ν is the kinematic viscosity of the fluid and is equal to μ/ρ_f . The magnitude of the Reynolds number indicates the relative significance of inertial (VD) and viscous (ν) forces affecting the motion.

According to Rouse (1938) viscous action may produce three essentially different types of resistance: deformation drag at very low Reynolds numbers, with the effects of viscous stress extending a great distance into the surrounding flow and causing a more or less widespread distortion of the flow pattern; surface drag at much higher Reynolds numbers, with appreciable deformation of the flow limited to a thin fluid layer surrounding the body; and form drag at still higher Reynolds numbers, arising if the form of the body is such that separation of the flow from the body occurs. The form of the body also determines to some extent the magnitude of the other two types of resistance. Rouse (1938) concludes that the resistance to motion of an immersed body depends only upon the Reynolds number characterizing the motion and the geometrical form (or shape) and orientation of the body.

Analytical determination of Newton's coefficient of resistance here called drag coefficient and represented by C_D for certain basic body forms has been possible only at very low Reynolds numbers. Stokes (1851) first determined analytically the drag resistance on a sphere falling through a fluid at very low Reynolds numbers ($R_e < 0.1$). Rouse (1937) rearranged Stokes' relationship into a form similar to Newton's (Equation 1).

$$F = \frac{24}{R_e} \quad A\rho_s \frac{v^2}{2} \quad (3)$$

obtaining the following relationship between Reynolds number and drag coefficient for very low values of R_e ,

$$C_D \times R_e = 24 \quad (4)$$

Oseen (1927) and Goldstein (1929) were able to extend analytically the range of Stokes' relationship to approximately $R_e = 2$. Beyond this limit the study of C_D as a function of R_e has remained empirical. Schiller (1932) plotted the known drag coefficients and Reynolds numbers on a $C_D - R_e$ diagram. Examination of Schiller's diagram shows C_D to be solely a function of R_e up to very high values ($R_e = 5,000$ for discs and $R_e = 500,000$ for spheres).

The shape of the immersed body determines significantly the drag resistance of the fluid at Reynolds numbers much higher than those at which Stokes' relationship is valid. At Reynolds numbers greater than 50 the drag coefficients for discs and spheres diverge noticeably in Schiller's diagram. Rubey (1933) and Zegrzda (1934) were among the first to recognize the effect of particle shape on drag resistance. The manner in which shape affects settling velocity can be expressed in terms of drag coefficient and Reynolds number (Wadell, 1934; Rouse, 1950; Albertson, 1953; Schulz, et al., 1954; Prandtl and Tietjens, 1957; Zeigler and Gill, 1959; Briggs et al., 1962).

Wadell (1933) was the first to define shape rigidly and he did so in terms of a sphere, since it has a higher settling velocity for a given volume than any solid of any other shape. Wadell (1934) pointed out that irregularly shaped solids do not have diameters in the geometric sense and that any computations using diameters must deal with spheres or relate some measurable property of the particle to a sphere. One such basic relationship is the nominal diameter, which is the diameter of a sphere having the same volume as the particle.

Several geometric shape expressions have been proposed involving a ratio of the triaxial dimensions of a particle: a = long axis; b = intermediate axis; and c = short axis (Briggs, et al., 1962). Krumbein (1942) suggested the following expression, which his investigations showed was related to sphericity as defined by Wadell:

$$\Omega = 3 \sqrt{\frac{b^2}{(a)(c)}} \quad (5)$$

Corey (1949) suggested a simplified shape parameter which he called the shape factor (S.F.):

$$\text{S.F.} = \frac{c}{(ab)^{\frac{1}{2}}} \quad (6)$$

where all axes were mutually perpendicular. Corey selected the expression $c/ab^{\frac{1}{2}}$ for his shape factor because he and others found that the particles usually oriented themselves in the fluid so that they presented the greatest resistance to the passing fluid, thus having the maximum projected area, as discussed by Wadell (1934) and Krumbein (1942), oriented normal to the path of motion. For this reason, Schulz, et al. (1954) considered Corey's shape factor a logical dimensionless shape parameter expressing the relative flatness of the particle. Corey found difficulty drawing lines of constant shape factor in a $C_D - R_e$ diagram using the triaxial measurements in the equations for C_D and R_e and concluded that the nominal diameter should be used for the characteristic length and area in the C_D and R_e parameters.

In reference to the use of triaxial measurements to represent the geometry of a particle, Schulz, et al. (1954) state that they may not be fully adequate but that they are simple and convenient and any more adequate system would be greatly complicated; and that it is highly improbable that a simple method can be devised to completely describe shape because of the great variability in shape found in natural sediments. Zeigler and Gill (1959) also state that the Corey shape factor may not be the best description of shape but point out, however, that it gives a reasonable correlation with drag coefficients and does indeed show that grains with different shapes plot in a predictable manner on a $C_D - R_e$ diagram. Zeigler and Gill (1959) used the data on natural sands of Schulz, et al. (1954) to compute graphs and tables of settling velocities of particles with different shape factors.

Briggs, et al. (1962) felt that although shape can be estimated from grain geometry, in studies of entrainment, transport, and deposition, it should be measured by means of its effect on the hydraulic properties of a similar particle having some ideal shape as suggested by Wadell (1932). Using a smooth sphere of equal nominal diameter, mass density and volume as reference, they developed a Dynamic Shape Factor (McCulloch, et al. 1960) by dividing the settling velocity of the nominal sphere (V_n) into the settling velocity of the particle (V_p):

$$DSF = (V_p/V_n)^2 \quad (7)$$

For particles affected by both inertial and viscous forces ($1 \leq R_e \leq 500$), the shape factor would be of the form:

$$DSF = a(V_p/V_n) + b(V_p/V_n)^2 \quad (8)$$

where

$$a + b = 1 \text{ and } (b/a) = R_e$$

Briggs, et al. (1962) found a good, but not perfect correlation between their hydraulic shape factor (DSF) and the common geometric shape factors, and gives regression formulae for estimation of DSF from triaxial shape factors. McCulloch, et al. (1960) applied a correction to the Corey shape factor depending on the values of the axial ratios, b/a and c/b , which apparently was used by Briggs, et al. (1962) in computing the regression formula for this factor.

DESCRIPTION OF PRESENT INVESTIGATION

Area of Investigation

The study area at Virginia Beach is located on the Atlantic seaboard 22 miles north of the Virginia-North Carolina State line, about 7.2 miles south of Cape Henry, and 19 miles east of Norfolk, Virginia (Figure 1).

Methods of Study

Sampling. Sand samples were collected at 25-foot intervals along three transects (Figure 1), normal to the seashore, from the berm zone to a depth of approximately 20 feet. Additional samples were collected at shorter intervals in the breaker zone at the 15th Street and 3rd Street transects (Table 5, Addenda). Sampling was accomplished by hand or with pipe dredges. Technicians attempted to sample only the upper 2 centimeters of the beach surface at all times. Offshore portions of the 15th and 3rd Street transects were sampled from existing fishing piers. The offshore portion of the transect at the Camp Pendleton boundary line was sampled from a U. S. Army DUKW at pipe stations 25 feet apart. Additional samples were collected at two places from the swash-backwash zone (Figures 1, 2), from the vicinity of Rudee Inlet (Figure 3) in the zone where the inlet outflow was expected to affect the sediment distribution, and from the top of the swash zone (Figure 2) at 200-foot intervals parallel to the shoreline. Samples along the transects were collected near the time of low water. Samples from the top of the swash zone, Rudee Inlet, and the swash-backwash zones were collected 2 to 3 hours earlier than those collected from the transects.

Samples from the berm, breaker, and shoaling wave zones of the three transects were mixed and subsamples from this mixture used for determination of the average shape factor (Table 3) and mineral composition (Table 2) for the whole area.

Determination of Shape Factor. A Corey shape factor was evaluated (Table 3) for the fractions of the mixture of sands (mentioned above) retained by No. 18 and No. 230 sieves (A.S.T.M. Sieve Scale). Triaxial measurements were made microscopically with the aid of an ocular micrometer and the calibrated fine-focusing adjustment knob. Since the shape factors calculated for both the coarsest and finest fractions were so close in value it was considered unnecessary to make shape factor determinations on any of the intermediate sized fractions.

The Dynamic Shape Factor (DSF) was computed (Table 4) only for samples from the 3rd Street pier transect, using Equation 8.

Determination of Mean Settling Velocities and Nominal Diameters. Forces acting on a sand grain that is settling in still water are the gravitational forces (acting downward), and the fluid resistance and buoyancy forces (acting upward).

Mathematically:

$$\text{Gravitational force } (F_g) = 4/3\pi r^3 \rho_s g \quad (9)$$

$$\text{Fluid resistance force } (F_r) = 6\pi r \mu v_p \frac{C_D R_e}{24} \quad (10)$$

$$\text{Buoyancy force } (F_B) = 4/3\pi r^3 \rho_f g \quad (11)$$

where

$$\rho_s = \text{density of grain in gm/cm}^3$$

$$\rho_f = \text{density of fluid in gm/cm}^3$$

$$r = \text{radius of sphere in cm}$$

$$\mu = \text{dynamic viscosity of fluid in gm/sec/cm}^2$$

$$v_p = \text{settling velocity of solid in cm/sec}$$

$$C_D = \text{drag coefficient} = \frac{F}{\frac{\pi}{4} d_n^2} / \rho_f \frac{v_p^2}{2}$$

$$d_n = \text{nominal diameter (mm), or the diameter of a sphere having the same volume as the particle}$$

$$R_e = \text{Reynolds number} = \frac{2r v_p \rho_f}{\mu}$$

At terminal fall velocity, the forces balance so that there is no net force,

$$F_g = F_R + F_B \quad (12)$$

and from the definition (2) of Reynolds number,

$$v_p = \frac{\mu R_e}{2r \rho_f} \quad (13)$$

When solving for v_p standard tables are available for the determination of μ and ρ_f (at various temperatures) and R_e may be determined from the tables of Schulz, et al. (1954) that take into account the drag coefficients associated with various particle shapes and densities.

If some expression is desired of the size of a particle settling at terminal velocity, such as nominal diameter d_n , one can solve for particle radius:

$$r^3 = \left[\frac{9 \mu^2}{4 \rho_f (\rho_s - \rho_f) g} \right] \cdot \left[\frac{C_D R_e^2}{24} \right] \quad (14)$$

All of the values for settling velocity and particle size reported in this study are based upon settling analyses run with a copy of the Woods Hole Rapid Sand Analyzer, WHRSA (Whitney, 1960; Zeigler, et al. 1960), and upon values found in tables published by Zeigler and Gill (1959). The Woods Hole settling tube (Figure 4) measures fall rates of all immersed sand grains over a 1-meter distance by sensing the changes of pressure produced by the sand suspension as a function of time. Electronics of the system used were identical to those published by Whitney (1960, Plate 4), with the exception that the bellows, pressure case, and the differential transformer were replaced with a Sanborn bidirectional, differential gas-pressure transducer (Figure 4). A resumé of the reliability and precision of the analyzer is presented by Zeigler, et al. (1960). Reproducibility of results is excellent.

Prior to analysis, samples were dried and split with a micro splitter. Because a few shell fragments larger than 4 mm. in diameter occurred in some of the samples, they were picked out of each of the sample splits. Final splits of 8- to 10-gm. weight were introduced into the analyzer.

It was assumed that there was no interparticle interference and no particle-wall interference during the sediment analyses. It was also assumed that surface roughness of the grains had a negligible effect on the measured fall velocities.

An output curve from a typical settling analysis performed on the analyzer is shown in Figure 5. By using a Gerber variable scale, it is a simple matter to scale off the height of a given curve into 100 equal divisions. If, then, one desires to estimate the median settling velocity of the sample he refers to the 50th percentile of the curve of pressure versus time. In the case of Figure 5, one obtains 24.2 seconds for the 1-meter fall, or a fall velocity of 4.2 cm/sec (at 24.2 seconds, 50 percent of the sample has settled one meter, as indicated by the pressure-time curve).

Zeigler and Gill (1959) developed a very useful set of tables for the conversion of particle settling velocity to particle diameter. Their tables express the solution of Equation 14 in terms of nominal diameter d_n , and are formulated for pure water at various temperatures over the range 20-27° C. The tables assume a particle density of that of quartz

(2.65) and have been computed for d_n in the range 0.1 through 2.0 mm. Their tables also employ the Corey shape factor (Equation 6). By using the median value of 24.2 seconds for the 1-meter fall result shown in Figure 5, one determines from Zeigler and Gill's tables that the median nominal diameter of the sample, for shape factor 0.7, at 26° C., is 0.289 mm.

The following nonparametric statistical measures were used for estimating mean settling velocity M_v , and mean nominal diameter M_z , from the analyzer curves

$$M_v \text{ or } M_z = \frac{P_{20} + P_{50} + P_{80}}{3} \quad (15)$$

where P_{20} , P_{50} , and P_{80} are the 20th, 50th, and 80th percentiles, respectively, and P is expressed in seconds for determining M_v , or nominal diameters, for determining M_z . Sorting of the distribution curve for nominal diameters was estimated with the following equation for the sorting coefficient:

$$S_o = \frac{P_{80} - P_{20}}{P_{50}} \quad (16)$$

Equation 16 was first used on similar data by Miller and Zeigler (1958). The closer S_o is to zero, the better is the sorting of the sample, for the spread of the size distribution decreases as S_o approaches zero.

Determination of Settling Velocity in Nature. Because it was desirable to obtain values for the settling velocities occurring in the natural environment, it was necessary to prepare curves (Figure 6) of settling velocity versus water temperature for representative samples of Virginia Beach sands from the study area.

Ten samples representative of the swash, breaking wave, and shoaling wave zones were run in fresh water and in sea water of 15.9, 26.8, and 38.9 o/oo salinity. Temperatures ranged from 39° to 120° F. Mean settling velocity values were determined from percentiles of the WHRSA curves using the statistic:

$$M_v = \frac{P_{10} + P_{30} + P_{50} + P_{70} + P_{90}}{5} \quad (17)$$

McCammon (1962) indicated that this statistic is 93 percent efficient, where the statistical efficiency of a graphic measure is the ratio of the variance of the distribution of the corresponding efficient estimate and the variance of the limiting distribution of the graphic measure.

Salinity affected settling velocity only slightly, the decrease in settling velocity between fresh and 39 o/oo salinity water being only about 5 percent. Difficulties in keeping the temperature constant in the settling tube and difficulties in obtaining representative 10-gram splits of the coarser grained samples for the WHRSA make the curves of Figure 6 accurate only to a first approximation. The curves are accurate enough, however, for expressions requiring the use of settling velocity values for aggregates of sand from the study area at Virginia Beach.

Settling velocities (V_p) for the natural environment (Temp. = 6.9° C; Salinity = 26.74 o/oo) on 25 March 1963 were used in the computations of dynamic properties of the particles.

The settling velocities of the corresponding nominal spheres (V_n) were extracted from the nomogram in Rouse (1937).

Determination of Reynolds Numbers and Drag Coefficients. Reynolds numbers based on the mean size were computed for each sample using the equation:

$$R_e = \frac{\rho_f d_n V_p}{\mu} \quad (18)$$

where

$\rho_f = 1.0209$ (from U. S. Navy H.O. Pub. No. 615)

$d_n = M_z$ in cm.

V_p = Mean settling velocity (in cm/sec) under prevailing conditions

$\mu = 0.0151$ poise (from Miyake and Koizumi, 1948)

Drag coefficients corresponding to these R_e values were extracted from Table 1, modified from Schulz, et al. (1954).

Reynolds numbers for the mean nominal spheres (R_n) corresponding to each of the samples from the 3rd Street pier transect were computed (Table 4) using the following equation from Briggs, et al. (1962):

$$R_n = \frac{V_n d_n}{\nu} \quad (19)$$

Drag coefficients corresponding to these R_n values were computed using another equation from Briggs, et al. (1962):

$$C_{D_n} = (DSF) (C_D) \quad (20)$$

where C_D is the drag coefficient of the actual grain, as obtained from Table 1, and DSF is from Equation 7.

A Reynolds number (R_p) was back calculated for the data from the 3rd Street pier transect using DSF values and again following Briggs, et al. (1962):

$$R_p = \sqrt{(DSF) (R_n)^2} \quad (21)$$

This computation was made as a check on the determination of the DSF value since R_p should in effect be equal to the previously computed R_e .

After computation of the R_e values it became obvious that the Reynolds numbers of the particles involved were quite low. The product of $R_e \times C_D$ was computed for many of the samples to obtain a comparison with the established constant value of $R_e \times C_D = 24$ (Equation 4) for particles within the realm of Stokes' law.

Mineralogy. The percentage by number of heavy minerals and rock and shell fragments was determined for each of the sieve fractions from the mixture of Virginia Beach sands (Table 2).

RESULTS AND DISCUSSION

Shape Factor

Table 3 presents the triaxial measurements and Corey Shape Factors for individual grains from fractions retained on Sieves Nos. 18 and 230. This table has been included for the use of those who may wish to try other shape factors based upon these measurements. The respective average S.F. for these fractions was 0.67 ($S = 0.15$) and 0.63 ($S = 0.13$). As can be seen from the standard deviations, S , variation around these means is not too great and therefore, our estimated average shape factor for each fraction represents the sample adequately. Because there is practically no difference in shape factor between the two fractions, they may be combined to obtain an average shape factor for sands of all sizes in the strip of beach under study. This is justified by the fact that no difference in shape factor is to be expected in grains of sizes intermediate between those measured when the latter, close in size to the largest and smallest grains present in the beach, failed to show any. The combined average S.F. is 0.65. For convenience in using the tables in Zeigler and Gill (1959) this shape factor was taken as 0.7. According to the U. S. Inter-Agency Committee on Water Resources (1958) a shape factor of 0.7 is about average for natural sediments.

Table 4 presents the Dynamic Shape Factor for samples from the 3rd Street transect. These were computed using Equation 8. The average DSF for the transect is 0.57 ($S = 0.03$). It was not possible to correlate this DSF value to our calculated S.F. of 0.7 using the regression formula for mixed Zingg groups given by Briggs, et al. (1962). Their equation,

$$DSF = 1.37 \text{ S.F.} - 0.08 \quad (22)$$

resulted in a $DSF = 0.87$ when $S.F. = 0.7$ was introduced into the equation and a $S.F. = 0.47$ when $DSF = 0.57$ was used. The discrepancy is more than likely due to the apparent use by Briggs, et al. (1962) of correction factors for S.F., as stated previously. It was impossible to ascertain these correction factors or their use from the data available. However, comparison of Reynolds number (R_p) back calculated using Equation 21 (Table 4), with the R_e computed for the same data using Equation 2 (Table 5) shows that they are very close. Thus, computations using either the Corey Shape Factor or the Dynamic Shape Factor yield almost identical Reynolds numbers values.

Size Analysis

Table 5 summarizes the data on size parameters for each of the samples collected. Figures 7, 8, and 9 graphically depict trends in values for the parameters. It is to be noted that the mean and median nominal diameters are very close in value in all transects. In all, the shoaling zone presents a more or less constant mean size throughout its extent. There is an abrupt increase in mean size in the breaker zone with a subsequent increase thereon inshore into the swash-berm zone. Nevertheless, some interesting differences in the distribution of mean size along the three transects are noticed. The greatest increase at the breaker zone is found at the 15th Street pier transect, while the smallest increase is found at the 3rd Street transect. The Pendleton Line transect presents an intermediate increase. However, the 15th Street transect shows the smallest mean size at the swash-berm zone with sizes much smaller than those at the breakers, while the 3rd Street transect evidences the greatest increase in mean size between the breaker and swash-berm zones with the swash-berm sizes much larger than those both at the breakers and at the swash-berm zone at the 15th Street transect. The Pendleton Line transect shows a pattern similar to that of the 3rd Street pier transect, but the largest mean size at the swash-berm zone is approximately the same as in the breakers.

The curves for sorting show the poorest sorting in the breaker zone at the 15th Street transect and Pendleton Line transect, but not at the 3rd Street transect. In the latter, sorting is relatively uniform throughout the length of the transect, with the poorest sorting found at the halfway point in the shoaling zone. The best sorting is found in all transects generally just inshore of the breaker zone, with good sorting present near the top of the swash-berm zone.

The average size parameters for the different beach zones in each of the three transects are shown in Table 6. The swash and berm zones above the swash zone at time of sampling are combined, because the lower limit of the berm zone was not established for this investigation. These data show in a very gross fashion that the mean size and median diameters tend to increase from the shoaling zone toward the swash-berm zone in the three transects, although the differences found are not very large. M_z and M_d do not change significantly between the breaker and swash zones at the 15th Street transect. Sorting in all transects is poorest in the breaker zone and best in the swash-berm zone, although the differences between zones are not very large except possibly at the Pendleton Line transect.

The average M_z and M_d for samples collected from the top of the swash zone are smaller than those for the combined swash-berm zone. This indicates that these parameters are smaller in the swash zone than in the berm zone since the data of Table 5 generally show higher values for the samples farthest inshore from the breaker zone.

Analysis of the data on size parameters for samples taken in the vicinity of Rudee Inlet is presented elsewhere (Harrison, Krumbein, and Wilson, 1964).

Reynolds Number and Drag Coefficient

Transects. The data for Reynolds number and drag coefficient for the infinite fluid of the settling tube are summarized in Tables 4 and 5, and Figures 7, 8, and 9. (Data for additional breaker zone samples appear in addenda to Table 5.) It is to be noticed that the curves for R_e follow almost perfectly the pattern of the M_z curves. This is as expected since the only variables in the equation used to calculate R_e were the mean diameter of the sample and the corresponding settling velocity, the kinematic viscosity of the water being constant. Thus, R_e is generally smallest in the shoaling and swash zones and highest in the breaker zone and toward the berm zone. C_D is a function of R_e in the range of R_e found in our study. In this range C_D varies inversely with R_e . Therefore, an almost perfect negative correlation exists between C_D and R_e , with lowest drag coefficients in the breaker and berm zones and highest in the shoaling and swash zones.

The R_e values for the samples from the three transects are quite small, most of them being smaller than 10. Very high Reynolds numbers were found only in the breaker zone samples collected as part of the swash-zone profiles. Related to these generally low R_e values are relatively high drag coefficients, as expected from the inverse relationship involved. It is to be noted that the kinematic viscosity of the sea water on the sampling day (1.91×10^{-5} ft²/sec) was relatively high and this contributed significantly to the low Reynolds numbers found.

The last column in Table 5 presents the product of Reynolds number and drag coefficient for most of the samples. In all cases they are more than the value of 24, given by Rouse (1937) for particles within the range of Stokes' relationship but seldom more than 48, or twice 24. Thus, owing to the relatively high viscosity of the sea water on 25 March 1963, the sand grains exhibited dynamic properties not too dissimilar from those to be expected for finer grains. It is interesting to note that this product ($Re \times C_p$) is almost the same for particles with shape factor of 0.7 and 1.0 up to Reynolds numbers of about 30 (Table 1).

The data for average Reynolds number of the different beach zones in the three transects appear in Table 6. These indicate that there is little or no difference in Reynolds number in the shoaling zone along the whole length of the area sampled. Several "t" tests showed that the differences were not significant ($P < 0.01$). Although differences between the breaker zones at the 3rd Street transect and the 15th Street and Pendleton transects appear to exist, "t" tests failed to show any difference between the three transects ($P < 0.05$) because of the large variances involved. Differences between the swash zone at the 15th Street transect and at the other two transects could be considered different in spite of the very few samples taken. Nevertheless, it should be kept in mind that a great variability among samples is characteristic of the swash zone (Krumbein and Slack, (1956) and, therefore, attribution of significance to this difference could be unfounded. Definite differences, corroborated by "t" tests ($P < 0.05$), are present between the swash-berm zone at the 15th Street transect and the other two transects, while the difference between the 3rd Street and Pendleton transects is not significant ($P < 0.01$).

Rudee Inlet Area. Figure 10 presents Reynolds number isolines for the stations in the vicinity of Rudee Inlet. The left-hand vertical axis demarcates the 3rd Street fishing pier. The dotted lines and arrow at the 400-foot mark on the lower horizontal axis indicate the approximate position of the inlet channel and direction of water flow at the time of sampling. Isolines $Re = 9$ and $Re = 13$ were not extended beyond their limits toward the 3rd Street pier because data collected from the pier a short time later indicated values much lower than 9 and 13. Thus, it may be assumed that the inshore and offshore components of these isolines become continuous on the south side of the pier. It is to be noted that Re values inside isoline $Re = 13$ can be quite high; e.g., 54.78 at station S-13.

Isoline $Re = 9$ can be considered to approximately demarcate the boundaries of the effect of the inlet outflow on the characteristics of the beach sediments. Reynolds numbers of 5 and 6, as shown by samples from stations outside of isoline $Re = 9$, are expectable since most of the stations were beyond the zone of significant breakers. This conclusion is supported by the data collected at the 3rd Street pier stations (Figure 8). Thus, the data show clearly the effect of the Rudee Inlet outflow in altering the normal pattern of distribution of sediment properties along the beach strip studied, as reflected by the distribution of Reynolds numbers.

Swash-backwash Zone. Trends of values determined for the samples taken in the swash-backwash zone (Figure 2) may be summarized as follows: mean size--slow increase in seaward direction over upper half of zone, rapid increase over lower half; sorting--best near landward side and in upper half of zone, rapidly becomes poorer in seaward direction in lower half of zone; Reynolds numbers under existing natural conditions (but for infinite fluid)--slow increase in seaward direction over upper half of zone, rapid increase over lower half. Limited data (Table 5) indicate that, for a given uprush, the mean size and Reynolds number are greater at slack water than after the backwash, on the upper five-sixths of the swash-backwash surface. As would be expected from this finding, sorting (Table 5) is worst at slack water of the uprush.

Mineralogy

Table 2 presents data on the relative abundance of components other than quartz grains found in the different sieve fractions of the mixed Virginia Beach sands. Heavy minerals were significantly abundant only in the residue fraction passing through the No. 230 sieve, while rock and shell fragments were of greatest significance in the fraction larger than 2 mm. It should be noted here that these two fractions were found to be a very small component of the mixture of sands both in numbers and in weight. Nevertheless, the presence of rock and shell fragments in the breaker zone is of great significance in the determination of size parameters and dynamic properties. Although the amount of sediment finer than 0.062 mm tends to increase offshore from the breaker zone, it can be assumed that its significance remains small in analysis of size and dynamic properties and may be considered negligible within the length of our transects. Zeigler, et al. (1960), state that a monomineralic (i.e., quartz) assemblage may be assumed when the quantity of heavy minerals is small.

Application of Data

The importance of the values presented in this descriptive study to the practical problems of beach nourishment and beach protection, and to many academic problems relative to the erosion, transportation, and deposition of sand, will come only when said values find their way into mathematical expressions. The values herein reported are for only a specific set of conditions. In order to demonstrate the possible use of the values, some equations are presented and mean or extreme sea-state and particle-characteristic values are substituted into them for illustrative purposes. The first example (Table 7) shows the dependency of the slope of the beach in the shoaling wave zone on particle and sea-state properties.

The slope values of Table 7 are determined from the average mean nominal-diameter values of Table 6 for the shoaling wave dynamic zone and are based on; (1) the measured values of water temperature and salinity

at Virginia Beach, taken by the U. S. Coast and Geodetic Survey (C. Taylor, 1963, oral communication), and (2) the mean value for wave period and the first mode for the distribution of wave heights for 5 years' running records of waves made at the U. S. Navy's Cape Henry wave gage. The average values of 5.3 seconds (for wave period) and 2.0 feet (for wave height) were determined by the significant height method of analysis. Mean water depth at the wave gage approximated 18 feet. The mean values (Table 7) for temperature, salinity, and kinematic viscosity at Virginia Beach are 56.8° F., 25.7 o/oo and $1.3 \times 10^{-5} \text{ ft}^2/\text{sec}$. Expectable upper and lower limits to these ranges are given in Table 7.

On the basis of several theoretical and laboratory studies, Eagleson, et al. (1963) developed an equation for the determination of the size of grains (D_e) in oscillating equilibrium on a sloping sand beach (neglecting reflection coefficient) of the form:

$$D_e = \left[131 \frac{H_o^2 \nu}{g TL_o} \left(\frac{s_f}{s_s - s_f} \right) \frac{f_1 \left(\frac{h}{L_o} \right)}{\sin \alpha} \right]^{7/6} \left[\frac{\pi}{\nu T} \right]^{2/3} \quad (23)$$

where

D_e = sand grain diameter, in feet

H_o = wave height in deep water, in feet

ν = kinematic viscosity of fluid (ft^2/sec)

L_o = wave length in deep water, in feet

g = gravitational constant, 32.2 ft. per sec^2

s = specific gravity of fluid or sediment, as specified

f_1 = a function, $f_1 \left(\frac{h}{L_o} \right) = \frac{\text{ctnh}^2 kh}{\sinh^2 kh + k_o h}$

Where: k = wave number = $2 \pi / L$

h = water depth

α = beach slope

Substitution of the values mentioned previously (into Equation 23) gives a measure of the effects of varying particle sizes (expressed as nominal diameters) and kinematic viscosities on beach slopes (Table 7) in the shoaling-wave zone. The three particle sizes chosen for Table 7 would correspond roughly to mean sizes of sand found: (1) offshore, within a few miles of Virginia Beach (0.12 mm), (2) in the dunes at Cape Henry and along Virginia Beach (Wentworth, 1930, Figures 112, 114, 115, and 116), and (3) offshore 10 to 40 miles in restricted zones (M. N. Nichols, 1963, oral

communication). The values of beach slopes for the various conditions (Table 7) are illustrative of expectable trends in slope modification only and are not recommended for the designing of future beach nourishment projects at Virginia Beach, without qualifications. For a further insight into the problem of slope modification the reader is referred to the entire paper of Eagleson, et al. (1963), especially the section on the equilibrium beach profile (1963, p. 43).

A brief investigation of dynamics in the swash-backwash zone was also made utilizing the expression of Ippen and Verma (1953) and the data of Figure 2 and Table 5.

Their equation, adapted here and solved for slope angle, is of the form:

$$\bar{V}_e = 0.12w \left[S^{\frac{1}{2}} \frac{d}{k_e} (S_s - 1.01) \right]^{-0.3} \quad (24)$$

where

$\bar{V}_e$ = the mean backwash edge velocity just large enough to initiate movement of a given sized particle

w = grain terminal fall velocity under natural conditions (ft/sec)

d_n = grain nominal diameter (feet)

S_s = specific gravity of grains (2.65)

S = slope of energy gradient

k_e = effective hydraulic roughness length (2.5 k, where k is average grain diameter of bottom)

To approximate $\bar{V}_e$, the maximum backwash velocity and depth were determined at the midpoint of the slope and the following relation solved for $\bar{V}_e$:

$$\bar{V} \max = \bar{V}_e \left[\frac{\log (1 + t_d/a)}{\log 2} \right] \quad (25)$$

where t_d = depth of flow and a = the boundary--reference axis distance. Surface samples of the sand were taken at the grid points or along the single lines shown in Figure 2, immediately after recession of the backwash. Backwash velocity was determined by introducing dye at slack uprush and timing its movement over a measured distance downslope. (Ten-minute averages of the heights of the plunging breakers at 13th Street and at Elm Street showed 0.9 and 1.2 feet, respectively, for samples taken on Figure 2.)

Results (not presented) of our attempts to test equation 24 for its applicability for prediction of swash-backwash slopes met with only limited success when the computed slopes were compared to those actually observed. Factors such as lift forces exerted on the grains due to groundwater movement through the foreshore face and the imprecision of the measurement techniques, may have contributed heavily to the inability to find a good correlation between observed and computed slopes.

Beach Model Comparisons

Miller and Zeigler (1958) developed a model relating dynamics and sediment patterns in the regions of shoaling waves, breaking waves, and the swash-backwash zone. Their model, based on theoretical considerations and published experimental results, was intended to hold for these dynamic zones "in a state of equilibrium." Miller and Zeigler's trend maps (1958, Figure 22) for median sediment size and for sorting throughout the three dynamic zones showed the trends summarized in Table 8. Also summarized in this table are the observed trends of this study (based on Figures 7, 8, and 9).

Table 8 indicates rather poor correlation between model and observed trends, the best correlation coming between predicted and observed median (mean) size in the breaker zone. Special effects, such as outflow of Rudee Inlet current at 3rd Street (Figure 1) and the presence of numerous pilings at the landward ends of the 3rd and 15th Street pier transects may have adversely influenced this comparison in three places. Still, the comparison is rather poor.

A further comparison of the observed trends for the swash-backwash zone, with the model trends of Miller and Zeigler's (1958) "foreshore" zone, shows that after backwash, observed sorting becomes poorer in the seaward direction. The model predicts improved sorting. Observations (Table 5, Figure 2) indicate an increase in mean size toward the sea in the swash-backwash zone, and this was predicted by the model.

SUMMARY REMARKS

It was the main purpose of this paper to attempt a description of the dynamic and related properties of the immersed beach sediment grains under the conditions prevailing at the time of sampling. An extension of the description over the range of expectable kinematic viscosities of sea water at Virginia Beach (Table 7) can be accomplished from the tabulated values of this report.

The calculations of Reynolds number involved the density and dynamic viscosity of Virginia Beach ocean water of 26.74 o/oo salinity at a temperature of 6.9° C. and the settling velocity of the particles of a

given size in such a fluid in a quiescent state. Since the density and viscosity of the water were constant, it follows that the differences in Reynolds number between particles were determined by their settling velocities (which in turn depended on the nominal diameter and specific gravity of the particles). Thus, the determinations of the Reynolds number are based directly on the settling velocity of the particles.

The numerical magnitude of the Reynolds number conveys the relative significance of the inertial ($V_p \times d_n$) and viscous (ν) forces in action. Reynolds numbers less than 0.001 say, would make one confident in ignoring inertial forces. Reynolds numbers higher than 1,000, on the other hand, would suggest that viscous forces might be ignored (although in reality these can never be entirely ignored). The results of this investigation, however, did not yield Reynolds numbers of such low or high magnitudes. The majority of our values ranged between 2 and 15 (Table 5).

Because the sediment sizes involved ranged around 0.250 - 0.300 mm, a predominance of inertial forces was expected. The viscosity of the water at the low temperature encountered at the time of sampling, however, was high enough to significantly reduce the magnitude of Re . Not only are the Reynolds numbers found relatively low but they fall within the range where laminar flow changes into turbulent flow, i.e., inertial forces take significant prominence over viscous forces. At Reynolds numbers above the range of Stokes' Law ($Re = 2$, as extended by Oseen and Goldstein) the flow lines around the particle separate from the particle surface and enclose a discontinuity; a wake or low-pressure zone is formed. When this separation is well formed, inertial forces predominate significantly. But this transformation to significant predominance of inertial forces is gradual. The zone of separation has a poorly defined appearance at $Re = 3$ but gradually takes on a more clearly defined appearance as the Reynolds number is increased until at $Re = 20$ the separation zone has a well-defined vortex downstream from the particle (Schulz, et al., 1954). It should be noted that within the range of $Re = 3$, to $Re = 20$, inertial forces are definitely greater than viscous forces, but the viscous forces still exert a significant influence in retarding the motion of the particles through the fluid.

The effect of the high kinematic viscosity of the sea water in lowering the magnitude of Re (and consequently increasing that of C_D) resulted in most of the sand grains exhibiting dynamic properties more akin to those of much finer grains which are subject to greater drag resistance. At the same time their dynamic behavior was not much different from that of perfect spheres since at these low Reynolds numbers the drag resistance on particles with S.F. = 0.7 and S.F. = 1.0 (as indicated by C_D values in Table 1) is almost identical.

The distribution of Reynolds numbers along the different beach zones in the three transects follows closely the distribution pattern of mean size values, as expected from the relationship between these two parameters.

The indicated trend is for the magnitude of the inertial forces to increase slowly toward the breaker zone where they reach their maxima. Shoreward of the zone of high breaker energy they decrease again. The extension of high Reynolds numbers in the swash-berm zone is an indication of the effect of previous waves breaking closer inshore at times of higher tidal reaches.

An important result of this investigation comes in the realization of the significant effect on the dynamic properties of the immersed sands exerted by the high kinematic viscosity of the ocean water at Virginia Beach at the time the study was conducted. This factor's importance was also confirmed in an independent investigation (Harrison and Krumbein, 1964) of the relative importance of various environmental parameters on mean size in the shoaling-wave zone at Virginia Beach.

ACKNOWLEDGMENTS

The authors are indebted to Mrs. Patricia C. Morales for her patient typing of drafts of this paper.

The help of Dr. John M. Zeigler and Mr. Carlyle Hayes in building a modified copy of the Woods Hole Rapid Sand Analyzer is much appreciated.

REFERENCES

- Albertson, M. L., 1953, Effect of Shape on the Fall Velocity of Gravel Particles; Proc. Fifth Hydraulics Conf., Univ. Iowa, Iowa City, pp. 243-261.
- Briggs, L. I., D. S. McCulloch, and F. Moser, 1962, The Hydraulic Shape of Sand Particles; Jour. Sedimentary Petrology, v. 32, pp. 645-656.
- Brown, C. B., 1950, Sediment Transportation, Engineering Hydraulics, edited by Hunter Rouse; New York, John Wiley and Sons, pp. 769-857.
- Corey, A. T., 1949, Influence of Shape on the Fall Velocity of Sand Grains; unpublished M. S. thesis, Colorado A. & M. College, 102 p.
- Eagleson, P. S., B. Glenne, and J. A. Dracup, 1963, Equilibrium Characteristics of Sand Beaches; Jour. Hydraulics Div., A.S.C.E., no. 3387, pp. 35-57.
- Goldstein, S., 1929, The Steady Flow of Viscous Fluid Past a Fixed Spherical Obstacle at Small Reynolds Numbers; Proc. Roy. Soc. London (A), vol. 123.
- Harrison, W. and W. C. Krumbein, 1964, Interactions of the Beach-Ocean-Atmosphere System at Virginia Beach, Virginia; Technical Memorandum No. 7, Coastal Engineering Research Center.
- Harrison, W., W. C. Krumbein, and W. Wilson, 1964, Sedimentation at an Inlet Entrance (Rudee Inlet-Virginia Beach, Virginia); Technical Memorandum No. 8, Coastal Engineering Research Center.
- Ippen, A. T. and R. P. Verma, 1953, The Motion of Turbulent Particles Along a Bed of a Turbulent Stream; Proc. Minn. Internat. Hydraul. Conv., Minneapolis, Minn.
- Ippen, A. T., and P. S. Eagleson, 1955, A Study of Sediment Sorting by Waves Shoaling on a Plane Beach; Beach Erosion Board Technical Memorandum No. 63, 83 p.
- King, C. A. M., 1959, Beaches and Coasts; London, Edward Arnold, Ltd., (Publishers), 403 p.
- Krumbein, W. C., 1942, Settling Velocity and Flume-Behavior of Non-Spherical Particles; Trans. Am. Geophys. Union 23, pp. 621-633.
- Krumbein, W. C. and H. A. Slack, 1956, Relative Efficiency of Beach Sampling Methods; Beach Erosion Board Technical Memorandum No. 90.

- McCammon, R. B., 1962, Efficiency of Percentile Measures for Describing the Mean Size and Sorting of Sedimentary Particles; Jour. Geology, v. 70, pp. 453-465.
- McCulloch, D., F. Moser, and L. Briggs, 1960, Hydraulic Shape of Mineral Grains; Geol. Soc. America Bull., v. 71, p. 1925.
- Miller, R. L. and J. M. Zeigler, 1958, A Model Relating Dynamics and Sediment Pattern in Equilibrium in the Region of Shoaling Waves, Breaker Zone, and Foreshore; Jour. Geology, v. 66, pp. 417-441.
- Miyake, Yasuo and Masami Koizumi, 1948, The Measurement of the Viscosity Coefficient of Sea Water; Jour. of Marine Research, v. 7, pp. 63-66.
- Newton, Isaac, 1687, *Philosophia Naturalis Principia Mathematica*, London.
- Oseen, C. W., 1927, *Neuere Methoden und Ergebnisse in der Hydrodynamik*; Akademische Verlagsgesellschaft Leipzig.
- Prandtl, Ludwig and O. G. Tietjens, 1957, *Applied Hydro- and Aero-Mechanics*; New York, Dover Publ., Inc. pp. 86-143.
- Reynolds, Osborne, 1883, An Experimental Investigation of the Circumstances which Determine Whether the Motion of Water Shall be Direct or Sinuous, and of the Laws of Resistance in Parallel Channels; Phil. Trans. Roy. Soc. vol. 174, Papers, v. 2, pp. 51-105.
- Rouse, Hunter, 1937, Nomogram for the Settling Velocity of Spheres; Nat. Research Council Ann. Rept., 1936-37, App. 1, Rept. Com. Sedimentation, 1937, pp. 57-64.
- Rouse, Hunter, 1938, *Fluid Mechanics for Hydraulic Engineers*; New York Dover Publ. Inc., 422 p.
- Rouse, Hunter, 1950, *Fundamental Principles of Flow; Engineering Hydraulics*, edited by Hunter Rouse; New York, John Wiley and Sons, pp. 1-135.
- Rubey, W. W., 1933, The Size Distribution of Heavy Minerals within a Water-laid Sandstone; Jour. Sedimentary Petrology, v. 3, pp. 3-29.
- Schiller, L., 1932, Fallversuche mit Kugeln und Scheiben, "Handbuch der Experimentalphysik", vol. IV-2, Akademische Verlagsgesellschaft m.b.H., Leipzig.
- Schulz, E. F., R. H. Wilde, and M. L. Albertson, 1954, Influence of Shape on the Fall Velocity of Sedimentation Particles; Colorado A. & M. Research Foundation Report to the Missouri Research Division, Corps of Engineers, U. S. Army, Omaha, Nebraska, M. D. Sediment Series, No. 5, 161 p. (Mimeographed).

- Shapiro, A. H., 1961, Shape and Flow; New York, Doubleday and Company, Anchor Books, 186 p.
- Stokes, G. G., 1851, On the Effect of the Internal Friction of Fluids on the Motion of Pendulums; Trans. Cambridge Philos. Soc., v. 9, pp. 8-106.
- U. S. Inter-Agency Committee Water Resources, 1958, Some Fundamentals of Particle Size Analysis; Inter-Agency Comm. Water Resources, Subcommittee Sedimentation, Rept. No. 12, Washington, U. S. Govt. Printing Office, 55 p.
- U. S. Navy Hydrographic Office, 1962, Tables for Sea Water Density; H. O. Publ. No. 615, 265 p.
- Wadell, H. A., 1932, Volume, Shape and Roundness of Rock Particles; Jour. Geology, vol. 40, pp. 433-451.
- Wadell, H. A., 1933, Sphericity and Roundness of Rock Particles; Jour. Geology, vol. 41, pp. 310-331.
- Wadell, H. A., 1934, The Coefficient of Resistance as a Function of Reynolds Number for Solids of Various Shapes; Jour. Franklin Inst., v. 217, pp. 459-490.
- Wentworth, C. K., 1930, Sand and Gravel Resources of the Coastal Plain of Virginia; Bull. 32, Va. Geol. Survey, pp. 1-146.
- Whitney, G. G., Jr., 1960, The Woods Hole Rapid Analyzer for Sands; Reference No. 60-36, Woods Hole Oceanographic Institution, Woods Hole, Mass.
- Zegrzda, A., 1934, Settling of Gravel and Sand in Clear Water; Leningrad Scient. Res. Inst. of Hydrotechnics Transactions, 12: 30-54.
- Zeigler, J. M. and Barbara Gill, 1959, Tables and Graphs for the Settling Velocity of Quartz in Water, above the Range of Stokes' Law; Reference No. 59-36, Woods Hole Oceanographic Institution, Woods Hole, Mass., 13 p., 55 tables and graphs.
- Zeigler, J. M., G. G. Whitney, Jr., and C. R. Hayes, 1960, Woods Hole Rapid Sediment Analyzer; Jour. Sedimentary Petrology, vol. 30, pp. 490-495.

TABLES

- 1 Drag coefficients as a function of R_e for naturally worn fragments.
- 2 Percent by number of mineral components in mixture of Virginia Beach sands.
- 3 Grain triaxial measurements and Corey Shape Factor of mixed Virginia Beach sands.
- 4 3rd Street Pier Stations. Computed dynamic properties of the nominal spheres and Dynamic Shape Factor of the particles.
- 5 Virginia Beach samples, March 25, 1963, 15th Street Pier.
- 6 Average statistical parameters for the different beach zones in the transects sampled.
- 7 Effect of water temperature and salinity and mean particle size or bottom slope in the shoaling-wave zone for a local mean (significant) wave height of 2.0 feet and period of 5.3 seconds and for a mean water depth of 18 feet.
- 8 Comparison between postulated trends of sediment parameters and observed trends.

Table 1.--Drag Coefficient as a Function of R_e for naturally worn fragments (Table 15, Schulz, et al., 1954)

R_e	C_D					$R_e \times C_D$	
	S.F.= 0.3	0.5	0.7	0.9	1.0	S.F.=0.7	S.F.=1.0
1.5	25.0	21.0	19.4		19.0	29.10	28.5
2	20.2	16.8	15.4		14.9		
3	14.9	12.4	11.2		10.8	33.60	32.4
4	12.0	9.9	8.9		8.6		
5	10.3	8.5	7.5		7.2		
6	9.1	7.45	6.5		6.3	39.00	37.8
7	8.1	6.7	5.85		5.6		
8	7.5	6.1	5.3		5.05		
9	6.9	5.65	4.9		4.65	44.10	41.8
10	6.5	5.25	4.55		4.3		
15	5.05	4.1	3.45		3.23	51.75	48.45
20	4.3	3.4	2.88	2.75	2.68	57.60	53.60
30	3.5	2.72	2.28	2.14	2.08	68.40	62.4
40	3.1	2.35	1.94	1.81	1.75		
50	2.85	2.11	1.74	1.59	1.56	87.00	78.0
60	2.70	1.95	1.60	1.45	1.40		
70	2.60	1.83	1.49	1.33	1.29	104.30	90.3
80	2.52	1.75	1.41	1.25	1.21		
90	2.47	1.67	1.35	1.18	1.14		
100	2.45	1.61	1.30	1.12	1.08	130.00	108.0
150	2.36	1.45	1.14	0.94	0.895		
200	2.34	1.38	1.07	0.84	0.79	214.00	158.0
300	2.37	1.30	1.02	0.75	0.67		
400	2.40	1.30	1.00	0.71	0.60		
500	2.45	1.31	1.00	0.695	0.555	500.00	277.5
600	2.50	1.33	1.02	0.685	0.528		
700	2.55	1.37	1.03	0.683	0.502		
800	2.59	1.40	1.04	0.680	0.488	832.00	390.4
1000	2.65	1.48	1.08	0.675	0.460	1080.00	460.0
1500	2.70	1.61	1.14	0.670	0.428		
2000	2.70	1.68	1.17	0.670	0.410	2340.00	820.0
3000	2.63	1.70	1.20	0.680	0.400		
4000	2.55	1.70	1.21	0.682	0.400		
5000	2.46	1.67	1.20	0.695	0.401	6000.00	2005.0
6000	2.38	1.66	1.19	0.700	0.402		
7000	2.31	1.63	1.18	0.705	0.404		
8000	2.26	1.61	1.17	0.705	0.406	9360.00	3248.0
10000	2.17	1.57	1.14	0.710	0.410	11400.00	4100.0
15000	2.11	1.40	1.08	0.711	0.414		

Table 2 .--Percent by number of mineral components in
mixture of Virginia Beach sands.

Sieve No.	Mesh size (mm)	% Heavy minerals	% Rock fragments	% Shell fragments
10	2.00	0	18	20
18	1.00	0	12	14
35	0.50	10	0	0
120	0.125	12	0	0
230	0.062	12	0	0
Residue	< 0.062	≈ 50	0	0

Table 3.--Grain triaxial measurements (in micrometer units)
and Corey Shape Factor of mixed Virginia Beach sands.

$$S. F. = c/(ab)^{\frac{1}{2}}$$

Sieve No. 18

a	b	c	S.F.	a	b	c	S.F.
61	56	20.88	0.35	53	50	27.60	0.53
45	30.21	28	0.75	106	58	39.91	0.50
38	30	27.60	0.81	47	36	20.51	0.49
56	53	40.65	0.74	43	36	26.85	0.68
57	62	53.71	0.90	50	40	31.70	0.70
56	40	25.73	0.54	55	45	31.33	0.63
59	45	11.19	0.21	76	57	57.44	0.87
65	56	17.53	0.29	63	48	34.31	0.62
64	37	23.49	0.48	49	40	32.07	0.72
86	59	17.00	0.23	54	46	26.85	0.53
51	34	16.78	0.40	72	46	42.89	0.74
51	32	23.87	0.59	45	40	33.19	0.78
75	36	35.06	0.67	43	38	25.73	0.63
40	36	27.23	0.71	57	43	33.04	0.66
54	53	32.45	0.60	60	43	33.04	0.65
39	38	32.82	0.85	91	64	32.30	0.42
56	41	32.82	0.68	58	42	31.55	0.63
66	55	41.03	0.68	55	47	43.49	0.85
55	47.37	44	0.86	52	48	44.98	0.89
42	41	27.60	0.66	52	49	44.61	0.88
59	47	39.53	0.75	81	55	44.61	0.66
53	39	29.46	0.64	102	54	39.76	0.53
86	53	37.30	0.55	45	43	28.57	0.64
56	45	34.31	0.68	50	38	23.34	0.53
49	36	35.68	0.82	57	43	37.52	0.75
110	57	46.99	0.59	69	62	46.84	0.71
79	50	26.11	0.41	79	50	37.07	0.58
50	54	39.91	0.76	56	34	31.55	0.72
78	63	48.86	0.69	68	41	29.61	0.56
51	31.70	31	0.77	56	43	34.91	0.71
65	56	44.76	0.74	74	43	41.99	0.74
62	47	33.19	0.61	76	65	58.41	0.83
56	57	20.09	0.51	101	56	48.34	0.64
76	40	40.65	0.73	44	40	28.57	0.68

a	b	c	S.F.
58	48	36.77	0.69
61	54	36.40	0.63
63	40	34.91	0.69
70	46	43.11	0.76
73	66	31.18	0.44
70	48	30.80	0.53
48	42	29.31	0.65
67	67	42.74	0.63
54	38	37.89	0.83
63	39	39.01	0.78
67	44.23	38	0.81
81	65	50.95	0.68
80	68	49.83	0.67
48	45	30.43	0.65
85	63	61.02	0.83
56	57	43.11	0.76
67	49.08	46	0.80
57	41	23.72	0.49
73	46.84	45	0.76
60	60	53.18	0.88
58	52.44	40	0.72
67	62	38.64	0.96
56	35	27.07	0.79
106	68	57.29	0.80
79	69.60	61	0.82
35	34.16	32	0.92
74	52	47.22	0.83
59	61	49.45	0.82
100	66	48.71	0.59
68	41.99	38	0.71
87	54	42.37	0.61
84	59	50.95	0.72

$$\Sigma x = 67.59$$

$$\bar{x} = 0.67$$

$$\Sigma x^2 = 47.93$$

$$(\Sigma x)^2/n = 45.684$$

$$n = 100$$

$$s^2 = 0.0227$$

$$s = 0.15$$

$$s\bar{x} = 0.015$$

Sieve No. 230

a	b	c	S.F.	a	b	c	S.F.
15	13	7.32	0.52	16	13	9.42	0.65
21	12	10.47	0.65	20	14	9.42	0.56
21	11	9.42	0.61	13	10	9.42	0.82
23	10	7.32	0.48	17	12	5.23	0.36
14	9	3.14	0.28	16	13	10.47	0.72
15	11.51	11	0.83	11	8.37	8	0.83
14	8	7.32	0.69	12	9	7.32	0.70
11	10	7.32	0.69	17	15	6.28	0.39
12	10	9.42	0.85	16	14	11.51	0.76
12	10	7.74	0.70	18	10	8.37	0.62
14	10	8.37	0.70	17	12	8.37	0.58
14	10	9.42	0.79	15	11.51	10	0.76
16	11	8.37	0.62	16	13	9.42	0.65
21	14	5.23	0.30	16	13	10.47	0.72
17	11	9.42	0.68	16	13	9.42	0.65
20	11	8.37	0.56	18	10	9.42	0.70
14	13	6.28	0.46	15	10	7.32	0.59
16	13	8.37	0.58	15	12	7.32	0.54
15	13	10.47	0.74	12	11	9.42	0.81
18	11	5.86	0.41	17	12	9.42	0.65
13	9	7.32	0.67	22	15	6.28	0.34
18	13	9.42	0.61	16	14	8.37	0.55
16	14.65	12	0.78	15	11	9.42	0.73
15	12	9.42	0.70	18	12	7.32	0.49
14	11	10.47	0.84	16	12	11.51	0.82
16	12	9.42	0.67	20	12	10.05	0.64
17	12	11.51	0.80	15	12	9.00	0.67
12	8	8.37	0.85	17	13	10.05	0.67
23	11	8.37	0.52	21	12	7.95	0.52
20	12	9.42	0.60	15	13	9.00	0.64
21	12	9.42	0.59	21	10	11.09	0.76
24	13	6.28	0.35	14	11	9.42	0.75
14	12	10.47	0.80	19	13	10.05	0.64
21	12.56	12	0.74	12	12	5.86	0.48
19	16	9.21	0.52	15	9	7.95	0.68
19	14	7.74	0.47	18	10	9.00	0.67
24	13	12.56	0.70	11	12.14	9	0.77
15	11.51	9	0.68	20	10	9.00	0.63
18	12	9.42	0.64	17	13	11.09	0.74
14	12	8.37	0.64	18	13	10.05	0.65
20	12	9.42	0.60	17	14	7.32	0.47

a	b	c	S.F.
13	10	10.05	0.88
16	12	10.05	0.72
15	10	10.05	0.82
12	12	7.95	0.66
15	15	9.00	0.60
22	11	7.95	0.50
14	12	7.95	0.61
15	10	5.86	0.48
18	13	9.00	0.58
19	12	7.95	0.52
19	12	7.95	0.52
14	14	7.95	0.56
19	14	7.95	0.48
12	11	7.82	0.63
21	13	10.05	0.60
18	13	10.05	0.65
18	11	7.95	0.56
18	10	9.00	0.67

$$\sum x = 63.32$$

$$s^2 = 0.016$$

$$\bar{x} = 0.63$$

$$s = 0.127$$

$$\sum x^2 = 41.73$$

$$s\bar{x} = 0.0127$$

$$(\sum x)^2/n = 40.09$$

$$n = 100$$

Table 4.--3rd Street Pier Stations. Computed dynamic properties of the nominal spheres and Dynamic Shape Factor of the particles.

Station	V_n	R_n	C_{Dn}	V_p^2/V_n^2	DSF	R_p^*
A	4.9	10.53	3.07	0.55	0.57	7.95
B	4.3	8.48	3.61	0.55	0.57	6.40
C	4.9	10.40	3.05	0.53	0.55	7.71
D	4.5	9.12	3.16	0.55	0.57	6.89
E	4.1	7.61	3.76	0.50	0.53	5.54
F	3.6	6.22	4.59	0.53	0.56	4.65
G	3.3	5.29	5.33	0.52	0.57	3.99
H	3.8	6.90	4.29	0.55	0.58	5.26
I	4.3	8.54	3.63	0.56	0.58	6.50
J	3.6	6.31	4.59	0.55	0.58	4.80
K	4.1	7.61	3.90	0.52	0.55	5.64
L	3.6	6.17	4.58	0.52	0.55	4.58
M	3.1	4.78	5.72	0.53	0.57	3.61
N	3.6	6.22	4.59	0.53	0.56	4.65
O	3.7	6.64	4.50	0.56	0.59	5.10
P	2.8	4.05	6.66	0.55	0.59	3.11
Q	3.7	6.61	4.50	0.56	0.59	5.08
R	4.1	7.55	3.81	0.50	0.53	5.50
S	4.1	7.64	3.85	0.52	0.55	5.67
T	5.6	13.21	2.69	0.55	0.50	9.34
U	4.3	8.39	4.17	0.55	0.57	6.33
V	3.1	4.63	6.30	0.49	0.53	3.37
W	4.4	8.80	4.01	0.55	0.57	6.64
X	3.3	5.41	5.77	0.55	0.58	4.12
Y	6.4	17.15	2.32	0.59	0.60	13.28
Z	6.2	16.11	2.41	0.58	0.59	12.37
AX	6.3	16.54	2.48	0.58	0.59	12.70
BX	6.5	18.21	2.45	0.64	0.65	14.67
CX	6.6	19.12	2.27	0.67	0.67	15.62
DX	5.9	14.81	2.51	0.58	0.59	11.38
EX	6.0	15.26	2.47	0.58	0.59	11.72
FX	6.5	17.90	2.23	0.59	0.60	13.87

* R_p is R_e for actual particle back calculated using equation $R_p = \sqrt{(DSF)(R_n)^2}$

Table 5
Virginia Beach Samples
March 25, 1963

15th Street Pier

Station	M _d	M _z	S _o	V _p	R _e	C _D	R _e × C _D
A	0.195	0.199	0.471	1.88	2.52	13.20	33.26
B	0.203	0.209	0.502	2.015	2.84	13.68	
C	0.226	0.238	0.619	2.415	3.88	9.36	
D	0.245	0.262	0.689	2.745	4.86	7.61	36.98
E	0.267	0.286	0.771	3.165	6.11	6.43	
F	0.252	0.266	0.722	2.825	5.07	7.40	
G	0.255	0.265	0.662	2.795	5.00	7.50	37.50
H	0.229	0.246	0.659	2.515	4.17	8.30	
I	0.237	0.257	0.734	2.665	4.62	7.94	
J	0.228	0.245	0.662	2.50	4.13	8.40	34.69
K	0.234	0.244	0.611	2.49	4.10	8.40	
L	0.249	0.266	0.682	2.825	5.07	7.40	
M	0.256	0.268	0.650	2.85	5.15	7.40	38.11
N	0.243	0.255	0.625	2.635	4.53	8.2	
O	0.272	0.291	0.683	3.235	6.36	6.27	
P	0.261	0.263	0.494	2.765	4.91	7.85	38.54
Q	0.242	0.252	0.615	2.595	4.41	9.16	
R	0.231	0.240	0.597	2.435	3.94	10.13	
S-T-U	----- Too Fine -----						
V	0.248	0.257	0.616	2.665	4.62	9.06	41.85
W	0.268	0.275	0.600	2.985	5.54	8.0	
X	0.249	0.267	0.714	2.835	5.11	8.44	
Y	0.262	0.267	0.625	2.835	5.11	8.44	43.12
Z	0.291	0.297	0.604	3.33	6.68	6.91	
AX	0.318	0.332	0.770	3.89	8.72	5.8	50.57
BX	0.547	0.569	1.060	7.685	29.55	2.79	82.44
CX	0.234	0.239	0.517	2.425	3.91	10.13	39.60
DX	0.300	0.302	0.520	3.41	6.95	6.74	46.84
EX	0.348	0.350	0.505	4.195	9.2	5.29	
FX	0.324	0.331	0.626	3.875	8.66	5.83	
GX	0.361	0.381	0.855	4.70	12.10	3.87	46.82
HX	0.291	0.302	0.518	3.41	6.95	6.74	
IX	0.306	0.314	0.529	3.615	7.67	6.28	
JX	0.374	0.376	0.558	4.625	11.75	4.17	48.99
KX	0.346	0.348	0.516	4.165	9.94	5.29	
LX	0.327	0.328	0.412	3.825	8.47	5.1	
MX	0.291	0.287	0.432	3.17	6.14	6.47	

(continued on next page)

Station	M_d	M_Z	S_O	V_p	Re	C_D	$Re \times C_D$
3rd Street Pier							
A	0.307	0.316	0.752	3.63	7.75	5.4	41.85
B	0.298	0.290	0.607	3.21	6.28	6.34	39.81
C	0.295	0.312	0.776	3.57	7.52	5.55	41.73
D	0.284	0.298	0.757	3.34	7.52	5.55	41.73
E	0.252	0.273	0.769	2.93	5.40	7.1	38.34
F	0.242	0.254	0.640	2.62	4.49	8.2	36.81
G	0.228	0.236	0.627	2.38	3.79	9.36	
H	0.247	0.267	0.748	2.83	5.10	7.4	
I	0.269	0.292	0.866	3.245	6.40	6.27	40.12
J	0.245	0.258	0.779	2.68	4.67	7.92	
K	0.243	0.273	0.921	2.94	5.42	7.1	
L	0.242	0.252	0.677	2.59	4.40	8.34	
M	0.208	0.227	0.721	2.265	3.47	10.05	34.87
N	0.230	0.254	0.852	2.62	4.49	8.2	
O	0.247	0.264	0.781	2.775	4.94	7.64	
P	0.207	0.213	0.531	2.075	2.98	11.3	33.67
Q	0.250	0.263	0.744	2.765	4.91	7.64	
R	0.262	0.271	0.629	2.91	5.82	7.2	
S	0.268	0.274	0.623	2.96	5.48	7.0	
T	0.346	0.347	0.705	4.14	9.70	5.39	
U	0.279	0.287	0.548	3.17	6.14	7.33	
V	0.220	0.220	0.327	2.175	3.23	11.90	
W	0.281	0.294	0.658	3.28	6.51	7.05	45.89
X	0.231	0.241	0.541	2.45	3.98	9.95	
Y	0.388	0.394	0.734	4.915	13.08	3.87	
Z	0.377	0.382	0.448	4.72	12.18	4.09	49.81
AX	0.386	0.386	0.393	4.78	12.47	4.22	52.62
BX	0.412	0.412	0.507	5.22	14.53	3.78	
CX	0.431	0.426	0.538	5.44	15.66	3.39	53.08
DX	0.368	0.369	0.535	4.52	11.27	4.27	
EX	0.369	0.374	0.444	4.595	11.61	4.20	
FX	0.397	0.405	0.596	5.035	13.78	3.73	51.39
Pendleton Line							
AA	0.420	0.424	0.554	5.415	15.51	3.40	52.73
A	0.401	0.410	0.576	5.18	14.35	3.59	
B	0.452	0.439	0.449	5.685	16.86	3.25	
C	0.440	0.433	0.531	5.56	16.27	3.31	53.85
D	0.337	0.348	0.528	4.155	9.76	4.66	
E	0.353	0.364	0.586	4.43	10.89	4.34	
F	0.259	0.268	0.555	2.85	5.15	7.35	37.85
G	0.270	0.276	0.648	2.955	5.51	7.00	
H	0.414	0.462	1.318	6.005	18.75	3.03	56.81
I	0.255	0.271	0.710	2.91	5.32	7.25	
J	0.254	0.263	0.625	2.765	4.91	7.85	
K	0.294	0.312	0.789	3.75	7.91	5.35	42.31
M	0.294	0.291	0.540	3.235	6.36	6.29	

(continued on next page)

Station	M _d	M _z	S _O	V _p	R _e	C _D	R _e × C _D
L	0.242	0.250	0.582	2.70	4.56	7.95	
N	0.253	0.265	0.648	2.795	5.00	7.5	37.5
O	0.245	0.256	0.661	2.65	4.58	7.94	
T	0.245	0.257	0.710	2.665	4.62	7.94	
R	0.242	0.256	0.719	2.65	4.58	7.94	36.36
X	0.245	0.255	0.689	2.68	4.61	7.94	
U	0.242	0.253	0.747	2.615	4.46	8.16	
W	0.226	0.236	0.716	2.375	3.78	9.36	35.38
V	0.263	0.278	0.859	3.035	5.69	6.06	
Q	0.258	0.276	0.837	2.955	5.50	6.20	
P	0.233	0.246	0.742	2.515	4.17	8.62	
P+300	0.151	0.197	0.927	1.85	2.46	13.72	33.75
Top of Swash Zone							
15-1	0.365	0.353	0.610	4.27	10.18	4.55	46.31
15-2	0.303	0.306	0.590	3.48	7.19	5.75	
15-3	0.296	0.303	0.564	3.43	7.02	5.85	
15-4	0.299	0.304	0.591	3.44	7.06	5.82	41.08
15-5	0.293	0.305	0.617	3.47	7.15	5.76	
15-6	0.331	0.338	0.637	3.99	9.11	4.86	
15-7	0.323	0.324	0.603	3.77	8.25	5.22	
15-8	0.375	0.389	0.810	4.83	12.69	3.89	49.36
15-9	0.361	0.384	0.872	4.75	12.33	4.11	
15-10	0.337	0.347	0.727	4.14	9.70	4.67	
15-11	0.283	0.289	0.593	3.20	6.24	6.41	
15-12	0.319	0.316	0.517	3.64	7.77	5.40	41.95
15-13	0.311	0.314	0.684	3.61	7.66	5.45	
15-14	0.367	0.361	0.544	4.38	10.68	4.33	
15-15	0.363	0.367	0.842	4.48	11.11	4.26	
15-16	0.378	0.370	0.626	4.54	11.35	4.22	47.89
15-17	0.339	0.348	0.828	4.16	9.78	4.65	
15-18	0.289	0.297	0.712	3.33	6.68	6.06	
15-19	0.265	0.273	0.618	2.94	5.42	6.65	
15-20	0.303	0.324	0.772	3.77	8.25	5.22	43.06
15-21	0.321	0.323	0.635	3.75	8.18	5.18	
15-22	0.288	0.287	0.538	3.17	6.14	5.98	
15-23	0.301	0.302	0.674				
15-24	0.395	0.360	0.544				
P-19	0.334	0.334	0.670	3.93	8.87	4.94	43.81
P-18	0.253	0.257	0.569	2.67	4.63	8.06	
P-17	0.296	0.295	0.611	3.30	6.57	6.13	
P-16	0.272	0.275	0.573	2.98	5.53	6.90	
P-15	0.244	0.246	0.479	2.52	4.18	8.62	36.03

(continued on next page)

Station	M _d	M _z	S _O	V _p	R _e	C _D	R _e × C _D
P-14	0.244	0.249	0.483	2.56	4.80	8.48	
P-13	0.252	0.257	0.575	2.67	4.63	8.06	
P-12	-	-	Missing	-	-	-	
P-11	0.257	0.257	0.505	2.67	4.63	8.06	
P-10	0.253	0.258	0.529	2.68	4.67	7.92	36.98
P-9	0.269	0.274	0.501	2.96	5.48	7.00	
P-8	0.256	0.264	0.554	2.78	4.95	7.60	
P-7	0.261	0.271	0.582	2.91	5.32	7.20	
P-6	0.242	0.255	0.640	2.64	4.55	8.10	36.85
P-5	0.267	0.280	0.685	3.07	5.80	6.70	
P-4	0.277	0.292	0.758	3.24	6.39	6.27	
P-3	0.263	0.269	0.577	2.87	5.21	7.30	
P-2	0.238	0.251	0.630	2.58	4.37	8.34	36.44
P-1	0.289	0.303	0.778	3.43	7.02	5.85	
Swash Zone Profiles							
Elm Street							
Grid -							
A-1	0.309	0.326	0.666	3.79	8.34	8.12	67.72
A-2	0.316	0.338	0.765	3.99	9.11	4.86	
A-3	0.452	0.553	1.676	7.44	27.81	2.40	
A-4	1.161	1.394	2.165	14.5*	136.65	1.20	163.98
B-1	0.316	0.326	0.686	3.79	8.34	8.12	
B-2	0.314	0.334	0.789	3.93	8.87	4.94	
B-3	0.595	0.721	1.800	8.2*	39.97	1.94	77.54
B-4	0.347	0.493	2.011	6.51	21.69	2.76	
C-1	0.313	0.353	0.945	4.27	10.18	4.11	41.83
C-2	0.307	0.342	0.856	4.06	9.38	4.74	
C-3	0.506	0.671	1.962	7.6*	34.47	2.15	74.11
C-4	0.301	0.301	0.558	3.39	6.89	5.92	
2nd Profile							
D-3	0.412	0.503	1.424	6.65	22.60	2.70	61.02
D-9	0.348	0.368	0.876	4.50	11.19	4.25	47.55
D-4	0.643	0.680	1.357	7.6*	34.94	2.13	74.42
D-10	0.350	0.475	1.671	6.19	19.87	2.95	58.61
D-5	0.983	1.012	1.480	11.0*	75.26	1.45	109.12
D-11	0.301	0.325	0.883	3.78	8.30	5.18	42.99
D-6	0.508	0.690	2.122	7.8*	36.38	2.06	74.94
D-12	0.490	0.755	2.622	8.4*	42.87	1.88	80.59
Swash Zone Profiles							
13th Street							
Grid -							
A-1	0.368	0.370	0.524	4.54	11.35	4.22	47.89
A-2	0.482	0.498	0.817	6.57	22.11	2.73	60.36
A-3	0.679	0.661	0.777	7.5*	33.51	2.16	

(continued on next page)

Station	M _d	M _z	S _O	V _p	R _e	C _D	R _e ×C _D
A-4	1.251	1.222	1.265	12.0*	99.14	1.31	129.87
B-1	0.339	0.344	0.622	4.09	9.50	4.70	
B-2	0.364	0.392	0.912	4.88	12.92	3.89	50.25
B-3	0.948	0.956	0.683	10.5*	67.86	1.51	102.46
B-4	0.806	1.178	2.531	11.8*	93.97	1.33	
C-1	0.350	0.357	0.631	4.33	10.44	3.67	38.31
C-2	0.346	0.346	0.624	4.13	9.65	4.69	
C-3	0.720	0.708	0.997	7.9*	37.81	2.00	75.62
C-4	2.528	2.441	0.520	21.3*	351.51	1.01	355.02
2nd Profile							
B-1	0.488	0.488	0.956	6.43	21.20	2.81	59.57
B-7	0.490	0.490	0.797	6.47	21.43	2.80	
B-3	0.806	0.806	0.392	8.9*	48.49	1.77	85.82
B-9	0.817	0.817	0.343	9.1*	50.26	1.73	
B-4	0.983	0.983	0.684	10.9*	72.43	1.40	101.40
B-10	0.730	0.730	0.863	8.2*	40.47	1.93	
B-5	0.830	0.830	1.077	9.3*	52.18	1.72	89.74
B-11	0.749	0.749	0.982	8.4*	42.53	1.91	
B-6	1.190	1.190	0.970	12.8*	102.98	1.29	132.84
B-12	1.087	1.087	0.827	11.8*	86.71	1.37	118.79
Off Rudee Inlet							
12N	0.417	0.414	0.698	5.26	14.71	3.44	50.60
S-11	0.303	0.292	0.633	3.24	6.39	6.20	
S-10	0.296	0.290	0.586	3.22	6.30	6.30	
S-9	0.288	0.283	0.586	3.12	5.96	6.50	38.74
S-8	0.284	0.270	0.637	2.88	5.25	7.20	
12-M	0.397	0.388	0.682	4.82	12.64	3.89	
S-7	0.290	0.286	0.552	3.16	6.10	6.43	39.22
S-12	0.410	0.395	0.589	4.93	13.16	3.79	
9-N	0.444	0.449	0.514	5.80	17.60	3.02	
S-13	0.473	0.853	0.526	9.5*	54.78	1.67	91.48
12-S	0.298	0.291	0.649	3.23	6.34	6.30	
9-M	0.405	0.409	0.547	5.17	14.29	3.60	
S-36	0.359	0.359	0.618	4.36	10.58	4.44	46.97
S-14	0.518	0.522	0.565	6.93	24.45	2.58	
S-25	0.377	0.382	0.510	4.72	12.18	4.11	
S-5	0.358	0.282	1.184	3.10	5.90	6.60	38.94
S-6	0.288	0.284	0.566	3.13	6.00	6.50	
8-S	0.350	0.382	0.418	4.72	12.18	4.11	
S-15	0.435	0.427	0.555	5.46	15.75	3.41	53.70
S-16	0.454	0.436	0.674	5.60	16.50	3.30	
S-17	0.384	0.340	0.705	4.03	9.26	4.83	
S-18	0.329	0.300	0.923	3.38	6.85	5.92	40.55

(continued on next page)

Station	M_d	M_z	S_o	V_p	R_e	C_D	$R_e \times C_D$
S-19	0.297	0.284	0.757	3.13	6.00	6.50	
S-20	0.251	0.238	0.676	2.41	3.87	9.10	
S-27	0.276	0.253	0.715	2.61	4.46	8.20	36.57
S-26	0.254	0.248	0.653	2.54	4.25	8.49	

ADDENDA

15th Street Pier Breaker Zone

Z	-	-	-	-	-	-	-
Z-2	0.309	0.284	0.809	3.13	6.00	6.50	
AX	-	-	-	-	-	-	-
AX-1	0.341	0.339	0.648	4.01	9.18	4.82	44.24
AX-2	0.311	0.296	0.760	3.32	6.63	6.13	
AX-3	0.281	0.274	0.667	2.96	5.48	7.00	
BX	-	-	-	-	-	-	-
BX-1	0.495	0.470	0.976	6.12	19.44	2.91	56.57
BX-2	0.319	0.315	0.641	3.63	7.72	5.45	
BX-3	0.254	0.250	0.556	2.57	4.34	8.45	
CX	-	-	-	-	-	-	-

3rd Street Pier Breaker Zone

S	-	-	-	-	-	-	-
S-2	0.316	0.316	0.658	3.64	7.77	5.42	42.11
T	-	-	-	-	-	-	-
T-1	0.324	0.317	0.697	3.66	7.84	5.39	
T-2	0.266	0.257	0.494	2.67	4.63	8.06	
T-3	0.288	0.279	0.548	3.05	5.74	6.72	38.57
U	-	-	-	-	-	-	-
U-1	0.264	0.259	0.463	2.70	4.72	7.47	
U-2	0.258	0.252	0.500	2.59	4.40	8.34	
U-3	0.267	0.266	0.462	2.82	5.07	7.51	38.07
V	-	-	-	-	-	-	-
V-2	0.290	0.288	0.506	3.19	6.20	6.64	
W	-	-	-	-	-	-	-

*These values were extrapolated from Figure 2 of Inter-Agency Committee on Water Resources (1958) and possibly are lower than what would have been obtained if the range of Figure 6's curves had been extended to include larger particle sizes.

Table 6 .--Average statistical parameters for the different beach zones in the transects sampled

	Md		Mz		So		Re	
	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
15th Street Pier								
Shoaling zone	0.255	0.199-0.291	0.243	0.195-0.272	0.636	0.471-0.771	4.63	2.52- 6.36
Breaker zone	0.333	0.239-0.569	0.336	0.234-0.547	0.728	0.517-1.060	9.78	3.91-29.55
Swash	0.324	0.300-0.348*	0.326	0.302-0.350*	0.512	0.505-0.520*	8.43	6.95- 9.92*
Swash-Berm	0.327	0.291-0.374	0.333	0.287-0.381	0.555	0.412-0.855	8.96	6.14-12.10
3rd Street Pier								
Shoaling zone	0.267	0.213-0.316	0.253	0.207-0.307	0.732	0.531-0.921	5.26	2.98- 7.75
Breaker zone	0.280	0.252-0.347	0.282	0.264-0.346	0.544	0.327-0.705	5.91	3.23- 9.70
Swash	0.256	0.231-0.281*	0.267	0.241-0.294*	0.599	0.541-0.658*	5.24	3.98- 6.51*
Swash-Berm	0.391	0.368-0.431	0.393	0.369-0.426	0.524	0.393-0.734	13.07	11.27-15.66
Pendleton Line								
Shoaling zone	0.259	0.197-0.312	0.245	0.151-0.294	0.726	0.540-0.927	4.49	3.78- 7.91
Breaker zone	0.318	0.263-0.462	0.298	0.254-0.414	0.825	0.625-1.318	8.62	4.91-18.75
Swash	0.259	**	0.268	**	0.555	**	5.15	**
Swash-Berm	0.400	0.337-0.439	0.403	0.348-0.439	0.537	0.449-0.586	13.94	9.76-16.86
Top of Swash Zone	0.304	0.246-0.389	0.299	0.238-0.395	0.629	0.479-0.872		

* Only two samples collected

** Only one sample collected

Table 7.--Effect of water temperature and salinity and mean particle size on bottom slope in the shoaling-wave zone for a local mean (significant) wave height of 2.0 feet and period of 5.3 seconds and for a mean water depth of 18 feet

Temp. (°F)	WATER		Particle nominal diameter (mm)	Slope indicated from Eq.(23) (degrees and minutes)
	Sal. (o/oo)	Kinematic viscosity (10 ⁻⁵ ft ² /sec)		
85.0	35.0	0.9	0.12	4° 35'
56.8	25.7	1.3	0.12	5° 30'
32.0	16.0	1.9	0.12	6° 18'
85.0	35.0	0.9	0.288	2° 09'
56.8	25.7	1.3	0.288	2° 33'
32.0	16.0	1.9	0.288	2° 58'
85.0	35.0	0.9	0.700	0° 55'
56.8	25.7	1.3	0.700	1° 07'
32.0	16.0	1.9	0.700	1° 20'

Table 8.--Comparison between postulated (Miller and Zeigler, 1958) trends of sediment parameters and observed trends (Figures 7, 8, 9).

Miller and Zeigler	This Study
<u>Shoaling-wave zone:</u>	
Sorting progressively improves moving shoreward to breaker zone	Sorting exhibits reversing trends (Figs. 7, 8) or improves shoreward (Fig. 9).
Median size increases shoreward to breaker zone.	Mean size increases slightly toward breaker zone (Fig. 9), stays roughly constant (Fig. 8), or shows reversing trends (Fig. 7).
<u>Breaking-wave zone:</u>	
Sorting best	Sorting worst (Figs. 7, 9) or relatively good (Fig. 8).
Median size largest	Mean size largest (Figs. 7, 9) or relatively large (Fig. 8).
<u>Foreshore zone:</u>	
Sorting irregular but relatively high near base, more regular but poorer near top	Sorting relatively high and uniform throughout extent (Figs. 8, 9) or irregular and high near base (Fig. 7) becoming high and uniform near top.
Median size progressively decreases moving landward	Mean size irregular (Fig. 7) or increasing landward (Figs. 8, 9).

FIGURES

1. Location of study area and station designations for sampling along transects and along top of swash zone.
2. Sampling grids and foreshore slopes at sites of swash-backwash sampling.
3. Sampling stations at Rudee Inlet.
4. Schematic diagram of Woods Hole Rapid Sand Analyzer.
5. Sediment analyzer output curve of pressure (P) versus time (T).
6. Settling velocity as a function of water temperature for samples from the shoaling-wave, breaking-wave, and swash zones. Curves are for fresh water and would be displaced about 0.01 cm/sec to left for water of maximum expectable salinity (36 o/oo).
7. Trends of values for mean size, M_z (nominal diameter); sorting, S_o ; and mean Reynolds number, R_e , for infinite fluid under natural conditions at 15th Street transect, 25 March 1963.
8. Trends of values for mean size, M_z (nominal diameter); sorting, S_o ; mean Reynolds number, R_e ; and mean drag coefficient, C_D , for infinite fluid under natural conditions at 3rd Street transect, 25 March 1963.
9. Mean size, M_z (nominal diameter); sorting, S_o ; and mean Reynolds number, R_e , for infinite fluid under natural conditions at north property line of Camp Pendleton, 25 March 1963.
10. Mean Reynolds number isolines for Rudee Inlet area, 25 March 1963.

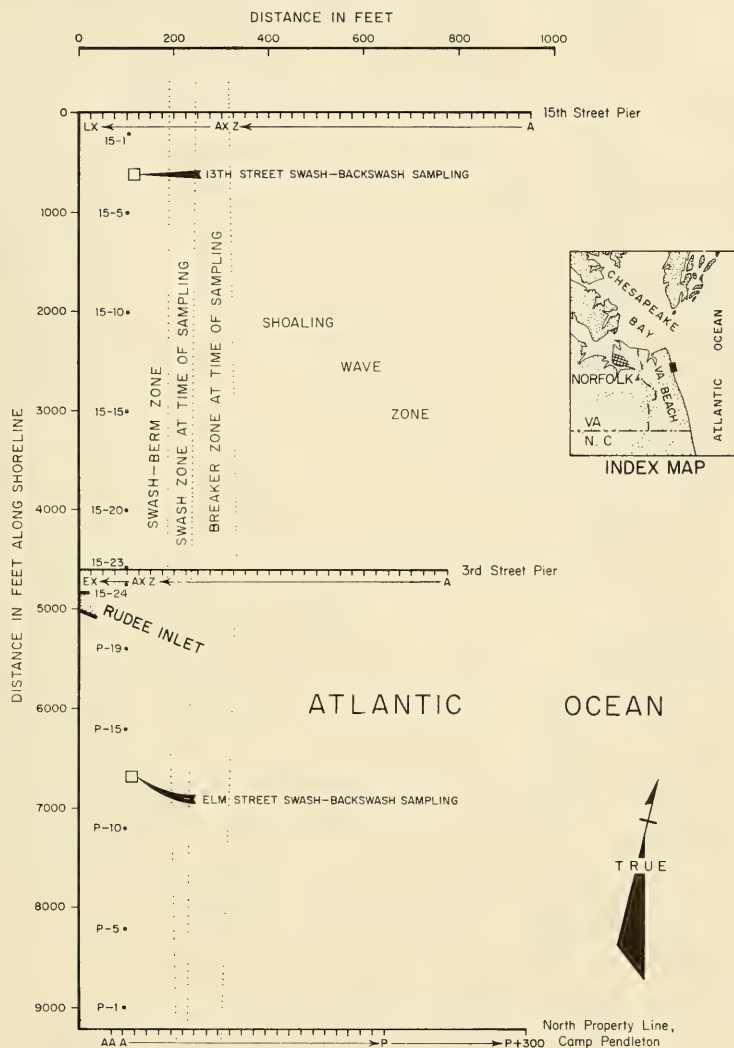
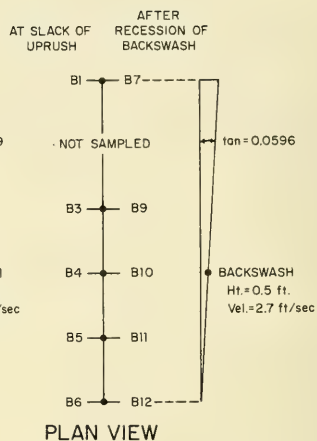
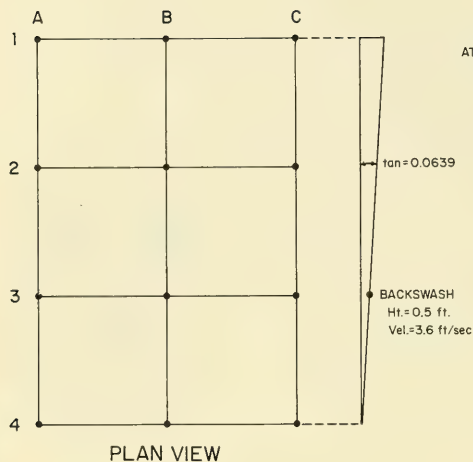


FIGURE 1. LOCATION OF STUDY AREA AND STATION DESIGNATIONS FOR SAMPLING ALONG TRANSECTS AND ALONG TOP OF SWASH ZONE.

13TH STREET



ELM STREET

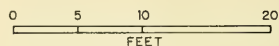
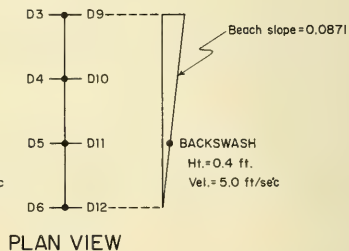
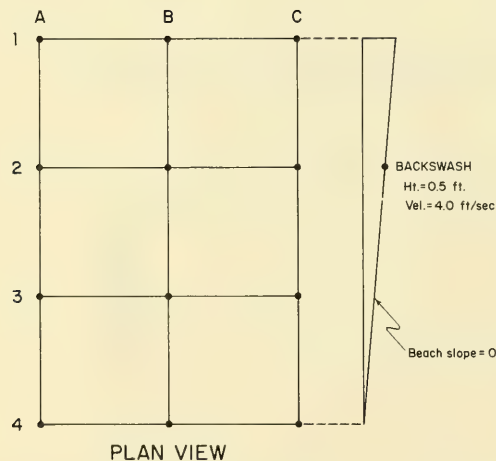


FIGURE 2. SAMPLING GRIDS AND FORESHORE SLOPES AT SITES OF SWASH-BACKSWASH SAMPLING.

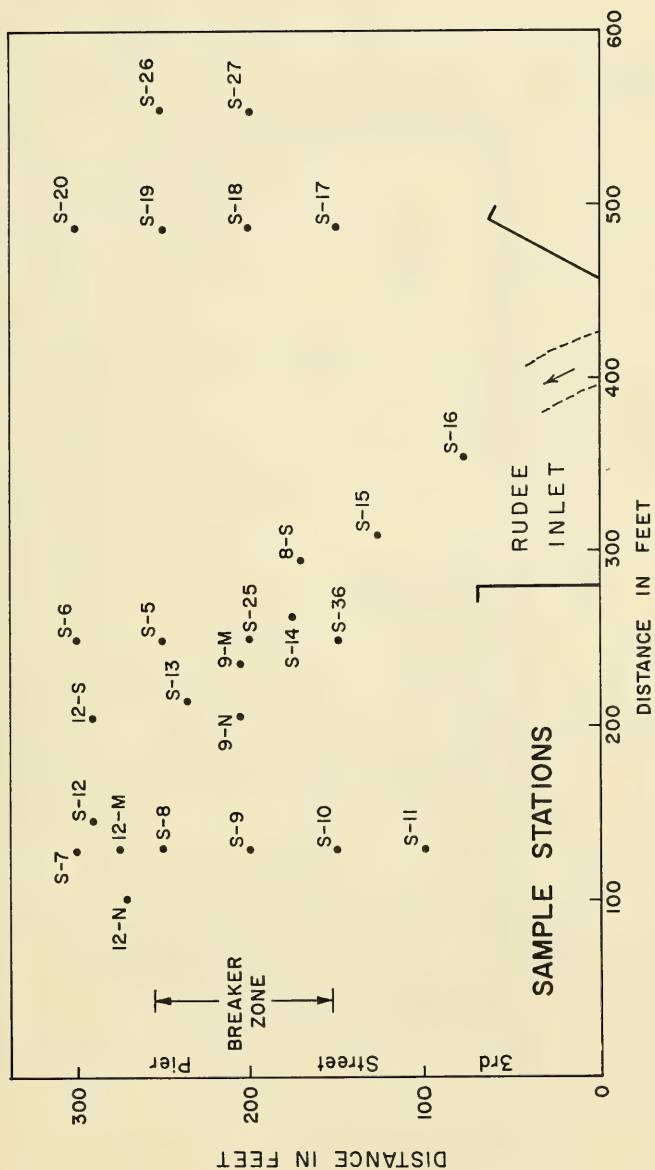


FIGURE 3. SAMPLING STATIONS AT RUDEE INLET.

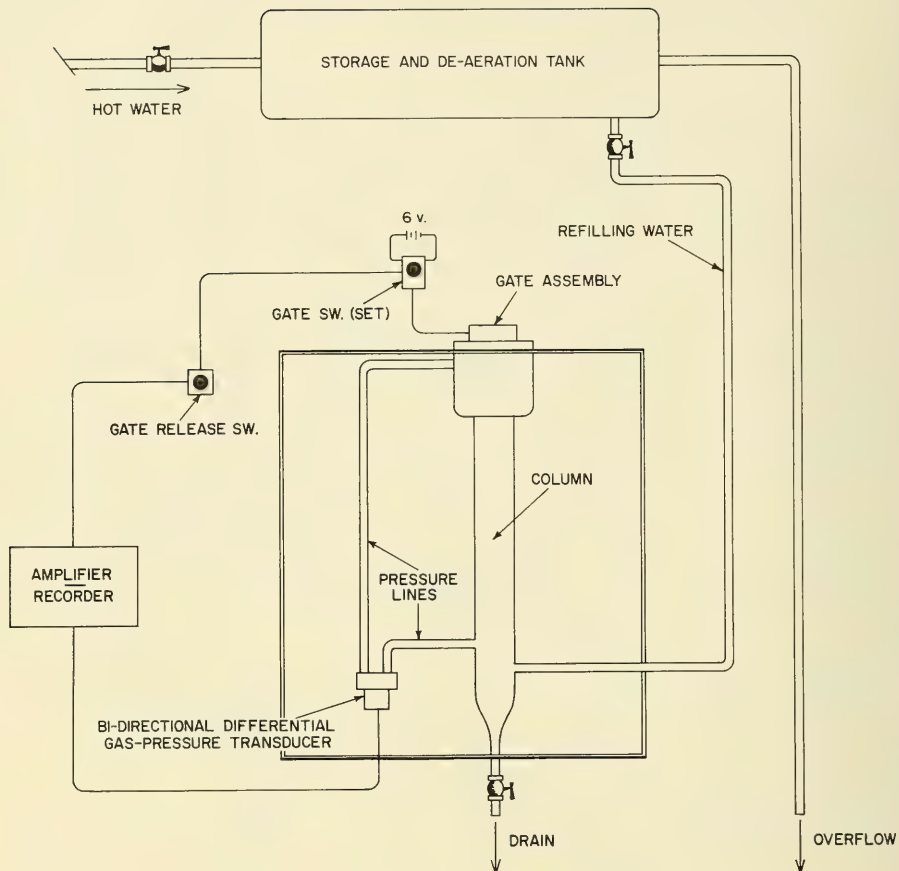


FIGURE 4. SCHEMATIC DIAGRAM OF WOODS HOLE RAPID SAND ANALYZER.

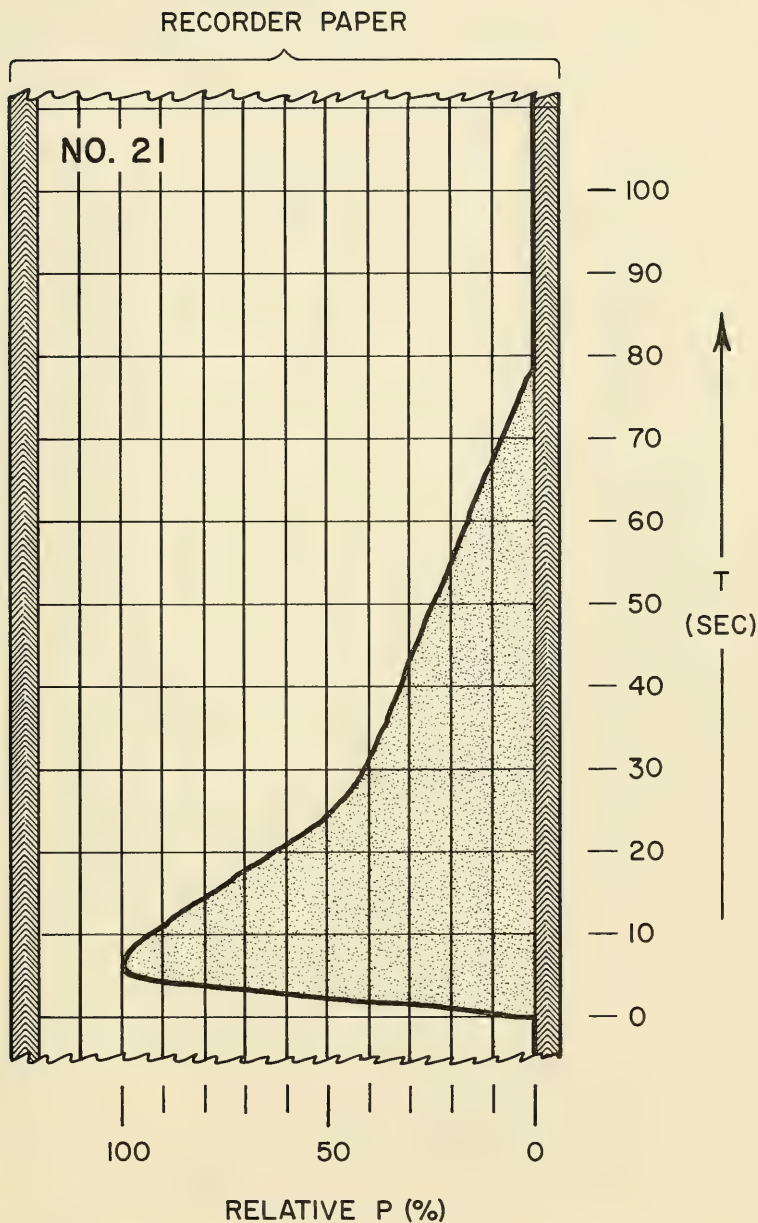


FIGURE 5. SEDIMENT ANALYZER OUTPUT CURVE OF PRESSURE (P) VERSUS TIME (T).

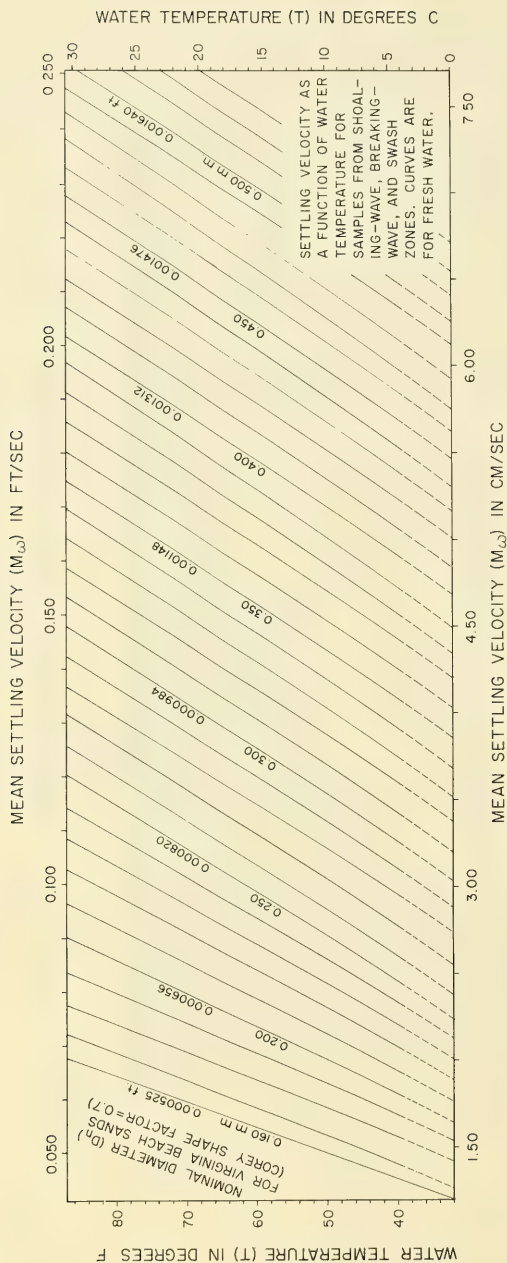


FIGURE 6. SETTLING VELOCITY AS A FUNCTION OF WATER TEMPERATURE FOR SAMPLES FROM THE SHOALING-WAVE, BREAKING-WAVE, AND SWASH ZONES. CURVES ARE FOR FRESH WATER AND WOULD BE DISPLACED ABOUT 0.01 CM/SEC TO LEFT FOR WATER OF MAXIMUM EXPECTABLE SALINITY (36 o/oo).

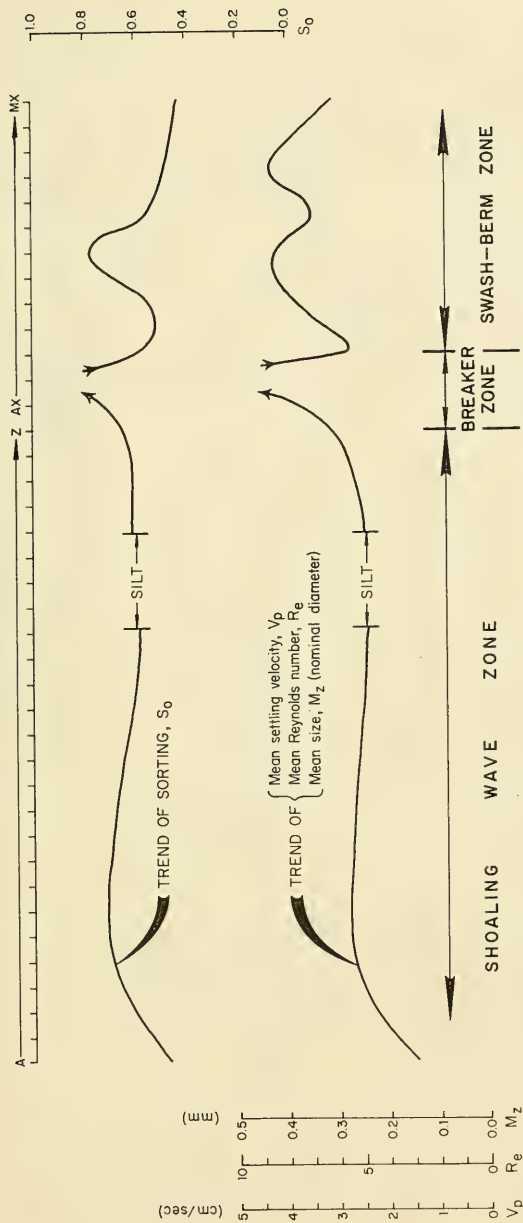


FIGURE 7. TRENDS OF VALUES FOR MEAN SIZE, M_z (NOMINAL DIAMETER); SORTING, S_o ; AND MEAN REYNOLDS NUMBER, R_e , FOR INFINITE FLUID UNDER NATURAL CONDITIONS AT 15TH STREET TRANSECT, 25 MARCH 1963.

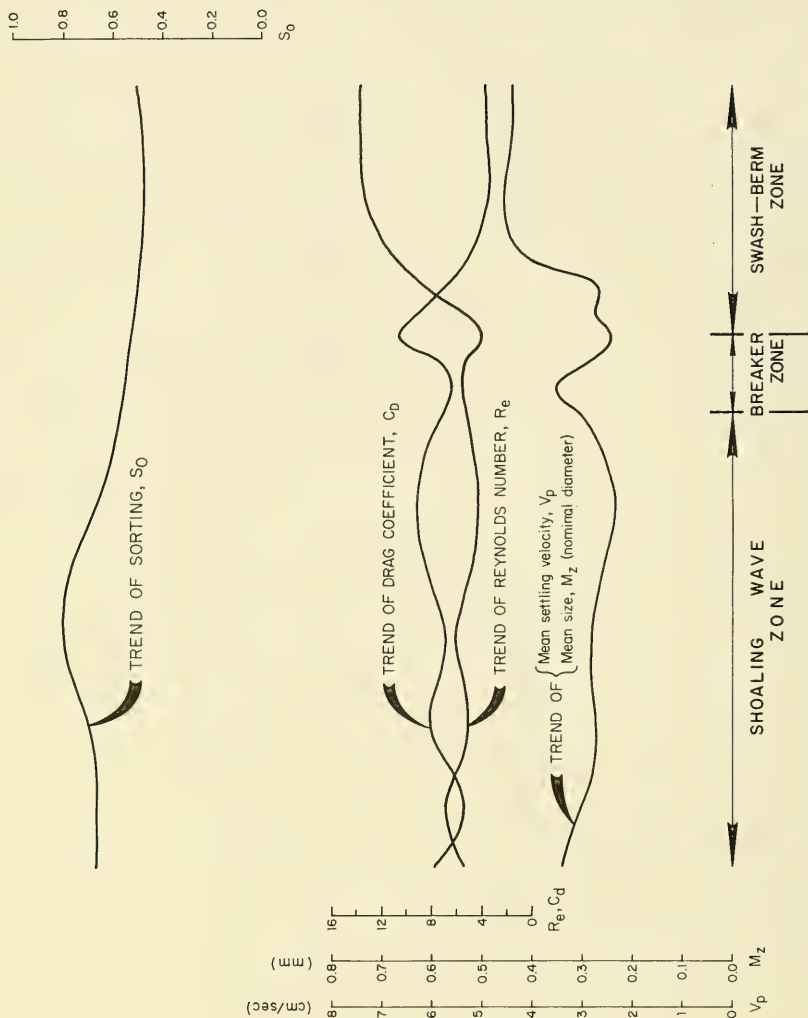


FIGURE 8. TRENDS OF VALUES FOR MEAN SIZE, M_z (NOMINAL DIAMETER); SORTING, S_o ; MEAN REYNOLDS NUMBER, R_e ; AND MEAN DRAG COEFFICIENT, C_D , FOR INFINITE FLUID UNDER NATURAL CONDITIONS AT 3RD STREET TRANSECT, 25 MARCH 1963.

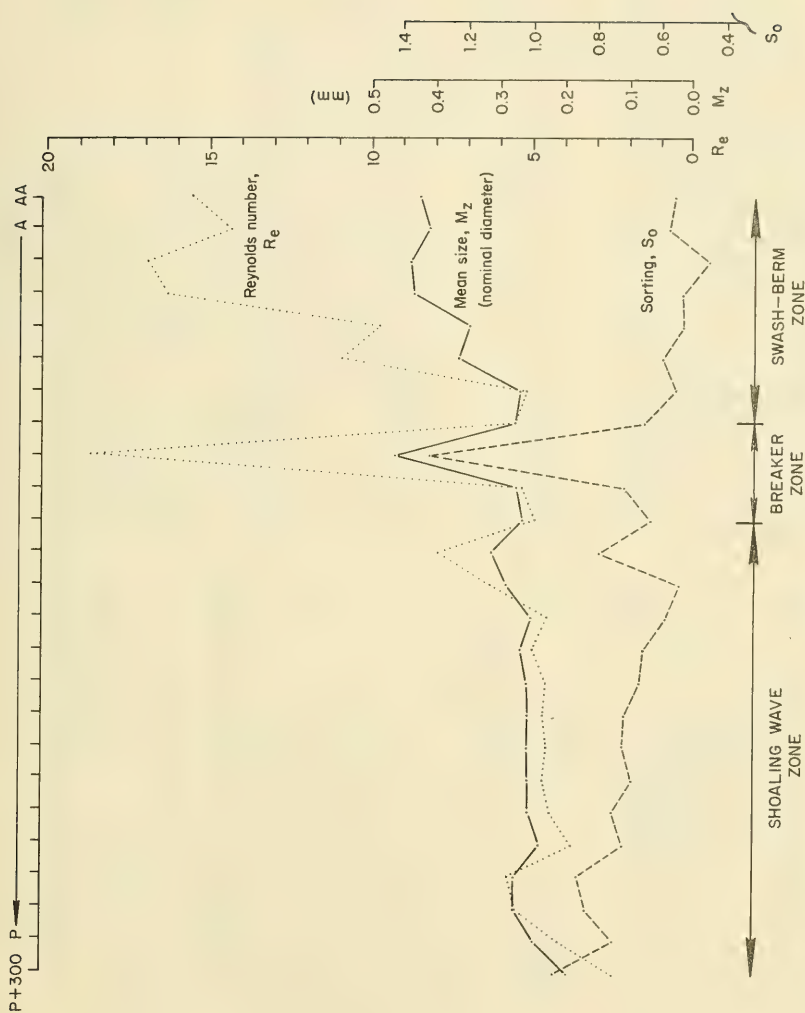


FIGURE 9. MEAN SIZE, M_z (NOMINAL DIAMETER); SORTING, S_o ; AND MEAN REYNOLDS NUMBER, R_e , FOR INFINITE FLUID UNDER NATURAL CONDITIONS AT NORTH PROPERTY LINE OF CAMP PENDLETON, 25 MARCH 1963.

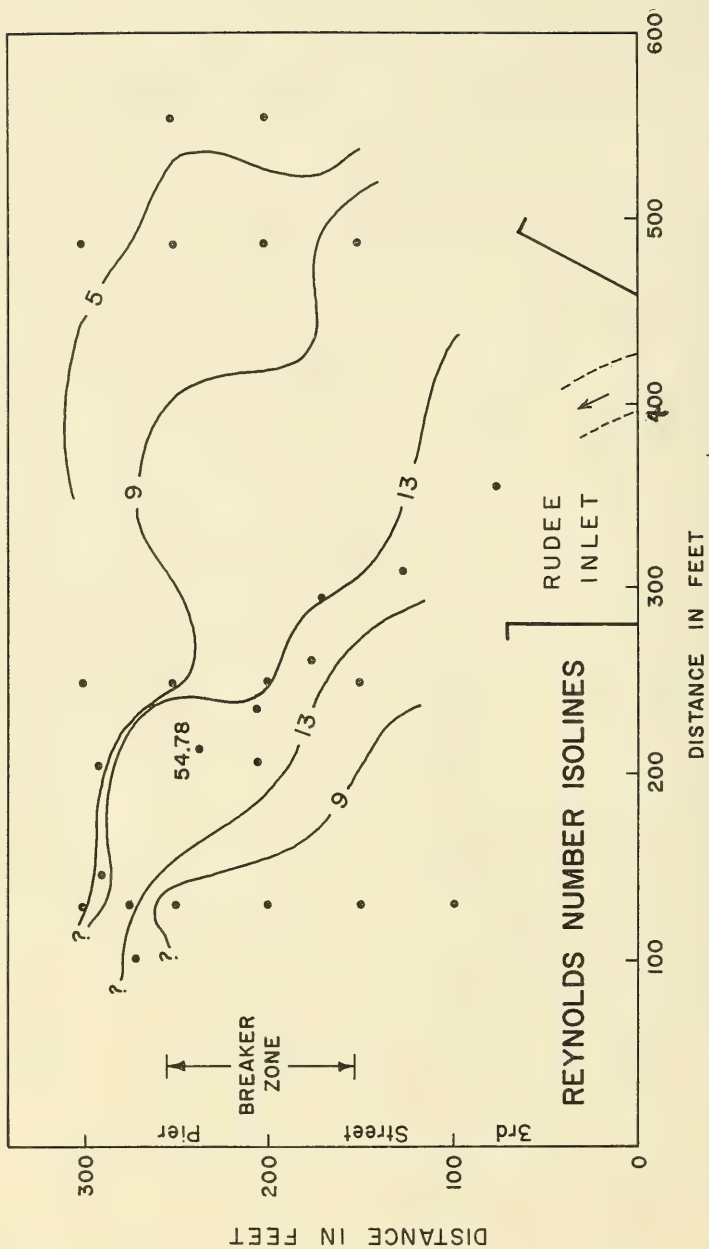


FIGURE 10. MEAN REYNOLDS NUMBER ISOLINES FOR RUDEE' INLET AREA, 25 MARCH 1963.

U.S. ARMY COASTAL ENGRG. RES. CENTER, CE, WASH., D.C. 1. Shore Processes
2. Virginia Beach, Va.
3. Sediment Analysis
4. Title
I Harrison, W.
II Morales-Alamo, R.

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Results are presented for a study designed to measure and analyze systematic variations in mean settling velocity of a large number of sand samples taken simultaneously along 3 transects across the beach and in the vicinity of Rudee Inlet. Measurements used to describe properties of the samples were: mean settling velocity, mean Reynolds number, and mean drag coefficient. Corey's shape factor and Dynamic Shape Factor of Briggs et al. were calculated and compared. The importance of kinematic viscosity on dynamic properties of sand particles and on beach slopes in shoaling-wave zone is considered. Observed trends of mean size and sorting throughout the dynamic zones are compared with those predicted by 1965-Miller and Ziegler Model, but comparison is poor.

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U.S. ARMY COASTAL ENGRG. RES. CENTER, CE, WASH., D.C. 1. Shore Processes
2. Virginia Beach, Va.
3. Sediment Analysis
4. Title
I Title
II Harrison, W.
III Morales-Alamo, R.

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